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CONTENTS

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IMPACT OF GRASS AND LEGUME BASED PASTURES ON BIOMASS PRODUCTION AND SOIL ORGANIC CARBON IN THE INTER-DUNAL SOILS OF INDIAN ARID ZONE

K.P. Tripathi[1] and V.K. Garg[2]

[1]*Project Directorate for Farming Systems Research Modipuram, Meerut, Uttar Pradesh*
[2]*Training Organiser, KVK, Gandhinagar, Gujrat*

Abstract

Field and laboratory experiments were conducted during 2002-2005 in the inter-dunal soils to monitor impact of improved pastures of grass and legumes on biomass production and soil organic carbon (SOC) in low fertile and prone to wind erosion. Pastures of sole grass (*Cenchrus ciliaris*), grass + legume (*Lablab purpureus*) and grass + legume (*Clitoria ternatia*) were introduced into natural unmanaged land (natural pasture) after clearing the vegetation. After 3 years of their introduction, there was 42.8, 34.6 and 30.6 per cent increase in soil organic carbon under *C. ciliaris* + *L. purpureus* and *C. ciliaris* + *C. ternatia* and *C. ciliaris*, respectively over soil under natural vegetation. Biomass of both shoots and roots increased under the combined pastures of grass and legumes. Soil organic carbon (SOC) increased under both the soil layers (plow and sub-surface) with introduction of improved pastures of *C. ciliaris*, C. *ciliaris* + *L. purpureus* and *C. ciliaris* + *C. ternatia* over the natural pasture. Highest SOC in plow soil was recorded under *C. ciliaris* + *L. purpureus* pasture followed by *C. ciliaris* + *C. ternatia* and sole *C. ciliaris*. However, difference in SOC in the sub- surface soils among pastures was marginal. About 0.33, 0.46 and 0.37 kg/m^2 SOC was added in the soil after 3 years of *C. ciliaris*, *C. ciliaris* + *L. purpureus* and *C. ciliaris* + *C. ternatia* cultivation, respectively. Distribution of SOC under plow and sub-surface soil added through sole *C. ciliaris* pastures was 60% and 40% in plow and sub-surface soils, respectively, but inclusion of *L. purpureus* and *C. ternatia* with *C. ciliaris* slightly increased the proportion of SOC in sub-surface soil. Root biomass and its N content were found related to the soil organic carbon build-up.

Key Words: *Cenchrus ciliaris*, *Lablab purpureus*, *Clitoria ternatia*, Soil Organic Carbon, Shoot biomass and Root biomass.

Sandy soil occupy 42.7 per cent of the total area of 11.4 Mha in the Indian arid zone which occur often in the form of dunes and hummocks, devoid of profile development and classified as Torripsaments (Dhir et al 1991). One major problem in these soils is the edaphically and anthropogenically diminishing of soil organic matter and deterioration of soil aggregate stability through unwarranted practices of cultivation of crops like pearl millet (*Pennisetum glaucum* L.) and overgrazing by the animals which destroy soil structure and uproot the plants while grazing and thus making soils devoid almost of vegetation cover (Yadav et al., 1997). These soils occur in less than 250 mm rainfall zone. Due to intense biotic pressure these are under severe degradation and need immediate attention (Joshi 1997). To bring these fragile soils under cultivation together with an objective of improving their productivity potential introduction of grasses and forage legumes in the beginning of their restoration process has been recommended by several workers like Thomas et al. (1997) and Lantz *et al* (2002).

Most studies on pasture improvements in the inter-dunal and sandy plains in arid region of India have focused on aspects of animal production, herbage production, and its utilization, whereas little attention have been paid to impacts on soil resource bases (Yadav et al., 1997). Further, more information is needed about changes in soil organic carbon with depth and with land use (Lal et al. 1996). Grasses introduced into the South American savannas have been shown to increase soil organic matter compared with the native grasses they replace (Fisher et al., 1998). Inclusion of pastures in crop rotation has been reported to maintain the soil organic carbon within the acceptable limit (Studdert et al 1997). The present study was conducted under National Agricultural Technology Project to improve degraded pasturelands in the arid region by introducing some prominent forage legumes like lablab bean (*Lablab purpureus L.*) and cordofan pea (*Clitoria ternatia*) along with buffel grass (*Cenchrus ciliaris*). The objectives of this study were (i) to see whether newly established improved pasture of grass legumes could improve in soil organic carbon in inter-dunal soils and (ii) to study the performance of these pastures on the inter-dunal pastureland productivity and to monitor their impact on soil organic carbon build-up in soil profile in relation to their root biomass, root quality and its decomposition in soil.

Materials and Methods

Experiments were conducted in the inter-dunal plains in the hot arid region of India during 2002 to 2004 in the Barmer District of Rajasthan. Study area lies between 72^0 0' to 72^0 15' E and 25^0 30' to 25^0 45' N and inhabited by sand dunes partially stabilized and moderately prone to wind erosion. Area is dominated by the *Dicanthimum-Cenchrus-Lasiurus* type grass covers of the Indian arid zone (Dabadghao and Shankarnarayan, 1973). General geomorphic characteristics of the area are presented in Table 1. Solis are classified as Typic Torripsamments (total sand content is more than 95%), variable in their depth (80cm to 170 cm), bearing uneven surface and very low moisture retention capacity (44.7 mm/m in soil profile). These soils are low in their fertility (soil organic carbon (SOC) 0.06-0.12% in surface (0-15 cm soil depth), available P_2O_5 9.8-13.8 kg/ha, extractable potassium 181-300 kg/ha), soil pH 8.4-8.5 and EC 0.6-1.1 dS/m. Experimental area was inhabited mainly by mixed xeromorphic reverine thorn forest comprising tees species of *Acacia nilotica*, *A. cupriformis*, *Salvadora oleoides*, S. *persica*, *Tamarix articulata*, *Tecomella undulata*, *Tamarindus indica*, *Albizia lebbeck*, *Ailanthus excelsa*, *Moringa oleifera* and *Ziziphus numalaria*, whereas the grass and shrub species which naturally occur were *C. ciliaris, Aristida adscensionis, Digitaria*

Table 1. Characteristics of the experimental area

Characteristics	Description
Mean annual rainfall	300-350mm
No. of rainy days	10-12 (erratic in nature)
Mean Maximum temperature	40^{0C}
Mean minimum temperature	10^{0C}
No. of dust storms	6-15
PET	1500-1700 mm yr^{-1}
Land form process	Fluvial and Aeolian geomorphic process
Surface features	Irregular slope (1-3%) with hummocks and low dunes

adscendens, Dactyloctenium aegyptium, Chloris virgata, Crotalaria burhia, Xanthium strumarium and *Indigofera cordifolia*.

Pasture establishment and biomass production

After clearing the natural vegetation (only grasses and bushes), 4 type of pastures namely, natural pasture (control), pasture of sole *Cenchrus ciliaris*, pasture of *Cenchrus ciliaris* intercropped with *Lablab purpureus* (1:1 in row to row) and pasture of *Cenchrus ciliaris* intercropped with *Clitoria ternatia* (1:1 in row to row) were established during *kharif* (July) 2002 in the plot size of 30 m x 2 m in 3 replications under Randomized Block Design at two locations namely, Balyana and Siwana villages situated at 30 km away from each other in the inter-dunal plains. Pure legume pastures could not be taken for the study because farmers of the area only agreed to raise grass based pastures. During 2002, the *Cenchrus ciliaris* (buffel grass) was established by transplanting grass root slips infected with mycorrhizal fungi (30-63% root infected with mycorrhizae of *G. mossae* and *G. fasciculatum*) in which above ground parts were removed by chopping just leaving 7-10 cm portion attached with the whole roots (Tripathi and Garg, 2005). Plants for the Grass root slips were taken from the 6-year-old *C. ciliaris* pasture from the experimental area of Central Arid Zone Research Institute, Jodhpur. After establishing grass in the field, seeds of forage legumes of *L. purpureus* and *C. ternatia* were sown (plant to plant distance of 30 cm) in alternate rows of *C. ciliaris* in the respective plots to maintain 1:1 ratio of grass to legume. *C. ternatia* was sown in first year and in subsequent years only gap filling was done because this legume is of perennial nature and due to its hardy and short bushy phenotypes it sustained during extreme summers. *L. purpureus* on the other hand *was* re-sown in same plots each year in fixed rows because of it was annual crop sustained only upto month of December. Weeding was done in first year after introduction of new pastures of grass and legume to facilitate newly established plants to avoid resistance from natural weeds and ephemerals. But in subsequent years, only weeds around 10 cm of plants of C. *ciliaris*, *L. purpureus* and *C. ternatia* were removed and rest of the field was left without weeding so that maximum biomass could be produced and also provide surface cover against wind erosion.

Plant and soil analysis

Shoot weight was recorded from cutting 1 m^2 area plants as for as possible near the soil surface. Plant shoot dry weight was recorded after oven drying. Root weight of the same plants from the same area were recorded by excavation and washing (Polonski and Kuhn, 2002). Roots were collected from 2 segments of the soil namely 0-20 cm (plow layer) and 20-100 cm (sub-surface layer) and washed and oven dried for record of weight and other analysis. During 2003 and 2004, 2 cuttings of grass could be obtained due to good rainfall, while only one cutting was taken during 2002. N content in shoot and roots were analyzed by methods of AOAC (1990). Plant biomass data were analyzed under the RBD experimental design for each year as per statistical procedures outlined by Panse and Sukhatme (1978).

After 3 years representative soil samples in triplicate from each plot were collected at different depth intervals from soil such as 0-10, 10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70-80, 80-90 and 90-100 cm in the profile. Samples were processed with 2 mm sieve and the organic carbon was determined by the procedure of wet oxidation method of Walkley and Black (1934). For interpretation of results, data on soil organic carbon were clubbed into two groups, namely plow layer soil (representing 0-20 cm soil depth, <20 cm) and sub-surface layer soil (representing 20-100 cm soil depth, >20 cm) and soil profile (0-100 cm, total profile). Per cent values of soil organic carbon were converted into kg/m^2 by taking depth-wise soil bulk density into account.

Plant root decomposition studies

A laboratory incubation (35^{0}C and 50% water holding capacity) experiment was conducted with the soils collected from experimental area to study decomposition of roots of natural pasture, *C. ciliaris*, *C. ciliaris* + *L. purpureus* (1: 1 ratio), *C. ciliaris* + *C. ternatia* (1: 1 ratio). Method proposed by Tarafdar and Rao (1992) were followed with some modification. About 3 g of finely ground dried roots were mixed with 2 kg of soil from respective plots with was kept under 5 L capacity wide mouthed (15.5 cm dia) and air tight stopper plastic bottle for 43 days (constant rate of CO_2 evolution). The moisture content of soil was maintained by gravimetrically throughout experiment. CO_2 evolved from the soil was trapped in 10 ml 1N KOH solution kept in test tube at intervals of 1, 3, 5, 7, 9, 12, 23 and 43 days after incubation. At these intervals, test tubes were being replaced by fresh test tubes containing KOH solution. The trapped CO_2 was measured by adding 10 ml of 10% w/v of $BaCl_2$. The remaining CO_2 was then measured daily by back titration with 0.1 N HCl using phenolphthalein indicator and bromo-phenol blue as indicators. Cumulative CO_2 evolved were plotted against time of incubation.

RESULTS AND DISCUSSION

Root and shoot biomass

Root and shoot biomass produced under improved pastures of grass and legumes (Table 2) suggested that biomass production for both the shoots and roots were lowest in the first year under all pastures of natural, sole *C. ciliaris*, *C. ciliaris* + *L. purpureus* and *C. ciliaris* + *C. ternatia*. Lowest mean dry biomass (876 and 339.6 kg/ha as shoots and roots, respectively) was recorded under natural pasture in all three years. Natural pasture was inhabited by a numbers of ephemerals, which just sprout after occurrence of rainfall, grow

Table 2. Total dry matter production (shoot and root) in the soils under different pastures

Pasture	Total dry matter yield (kg/ha)							
	Year 1		Year2		Year 3		Mean	
	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root
Natural	1082	403	938	378	608	238	876	339
C. ciliaris	4109	635	4538	764	2102	862	3583	753
C. ciliaris + *L. purpureus*	4074	764	4865	920	3605	984	4181.1	889
C. ciliaris + *C. ternatia*	5301	1198	5682	1693	4028	1832	5003.6	1574
CD (<0.05)	178	73	251	168	306	207	287	103

for a period of 15 to 35 days and complete their life cycle in a very sort span. Eventually, the root and shoot biomass produced by these ephemerals in the natural pasture is very low. On the other hand, when improved pastures of grass and legume were introduced, biomass productivity was increased significantly. Both root and shoot biomass were significantly higher in all three years in all three improved pastures of *C. ciliaris*, *C. ciliaris* + *L. purpureus* and *C. ciliaris* + *C. ternatia* over natural pasture. Pasture of *C. ciliaris* + *C. ternatia* produced highest root biomass as 1198, 1693 and 1832 kg/ha in the first, second and third years, respectively. It was followed by the pasture of *C. ciliaris* + *L. purpureus* as 862, 920 and 984 kg ha^{-1}, respectively in first, second and third years, respectively. Root biomass produced by sole *C. ciliaris* was more than natural pasture but lower than its combinations with legumes for all three years. Results clearly indicated that introduction of *C. ciliaris* with forage legumes enhanced the biomass productivity of the roots. Shoot biomass production under different pastures followed the similar trend as with the root biomass. Combination of *C. ciliaris* and *C. ternatia* produced highest shoot dry biomass in all three years which was followed by the *C. ciliaris* + *L. purpureus*, sole *C. ciliaris* and natural pasture.

Distribution of roots under different pasture in the plow and sub-surface layers in the soil suggested maximum root biomass in the plow layer (Table 3). Lowest root biomass was observed in natural pasture in both plow and sub-surface layers as 261 ±36 and 78 ±11 kg/ha, respectively. Highest root biomass was recorded under pasture of *C. ciliaris* + *C. ternatia* both in plow and sub- surface layers as 1054 ±111 and 520 ±48 kg/ha, respectively, which was followed by the *C. ciliaris* + *L. purpureus* and *C. ciliaris* alone for both the soil depths. Thus, introduction of sole C. *ciliaris* produced 2.065 and 2.74 times more root dry biomass in plow and sub-surface layers, respectively than the natural pasture. Combination of pasture legumes further increased the root biomass. *C. ciliaris* + *L. purpureus* produced 2.14 and 3.76 times more root biomass in plow and sub-surface layers, respectively than the natural pasture and about 1.04 and 1.37 times more root biomass in plow and sub-surface layers, respectively than the *C. ciliaris* alone. *C. ciliaris* + *C. ternatia* produced 4.038 and 6.67 times more root biomass in plow and sub-surface layers, respectively than natural pasture, 1.95 and 2.42 times more root biomass in plow and sub-surface layers, respectively than sole *C. ciliaris* and 1.88 and 1.77 times more root biomass in plow and sub-surface layers, respectively than the *C.*

Table 3. Root distribution in soil under different pastures at different depths

Pasture	Root dry weight (kg/ha)		Root density (g/m^3)		Plow: sub-surface dry root ratio
	Plow	Sub-surface	Plow	Sub-surface	
Natural pasture	261 ±36	78 ±11	174.6	9.2	3.35
C. ciliaris	539 ±62	214 ±23	365.3	25.2	2.53
C. ciliaris + *L. purpureus*	559 ±83	293 ±24	373.2	34.5	1.9
C. ciliaris + *C. ternatia*	1054 ±111	520 ±48	709.1	83.40	2.20

ciliaris + *L. purpureus* pasture. On soil profile basis, root biomass in case of combination of *C. ciliaris* and *C. ternatia* were 4.64, 2.09 and 1.77 times more than the natural, *C. ciliaris* and *C. ciliaris* + *L. purpureus*, respectively.

Soil organic carbon (SOC)

After 3 years of introduction of improved pastures of *C. ciliais*, *C. ciliaris* + *L. purpureus* and *C. ciliaris* + *C. ternatia*, there was significant impact of improved pastures of grass and legumes on the soil organic carbon (SOC) in plow (< 20 cm depth) and sub-surface (> 20 cm up to 100 cm depth) layers (Fig. 1). There was significant increase in SOC in case of *C. ciliaris*, *C. ciliaris*+ *L. purpureus* and *C. ciliaris* + *C. ternatia* pastures over the natural unmanaged land as 0.594, 0.682 and 0.594 kg/m² in the plow layers, respectively. SOC was highest under *C. ciliaris* + *L. purpureus* pasture but there was no significant difference in SOC in the plow layer between the pastures of *C. ciliaris* and *C. ciliaris* + *C. ternatia*. However, the lower values of standard error of mean under *C. ciliaris* + *C. ternatia* as compare to *C. ciliaris* indicated the better consistency in SOC throughout the plots under *C. ciliaris* + *C. ternatia*. Unlike plow layer, there was no significant difference in the mean values of sub- surface SOC among the improved pastures of grass and grass + legumes. In the sub-surface 0.682, 0.814, 0.854 and 0.854 kg/m² was recorded under natural, *C. ciliaris*, *C. ciliaris* + *L. purpureus* and *C. ciliaris* + *C. ternatia*, respectively. However, all three improved pastures had higher SOC in the sub-surface layer over natural pasture. On the basis of whole soil profile (up to 100 cm), SOC under different pastures were 1.078, 1.408, 1.536 and 1.440 kg/m² under natural, *C. ciliaris*, *C. ciliaris*+ *L. purpureus* and *C.*

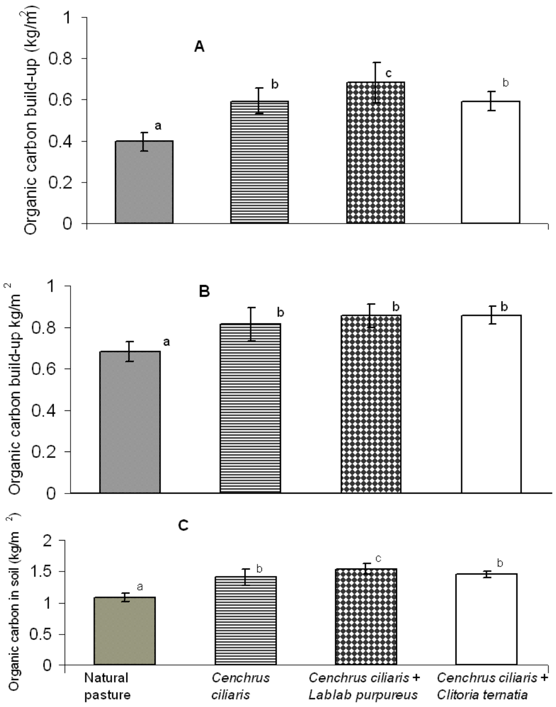

Fig. 1. Impact of improved pastues of grass and legumes on SOC in inter-dunal soils after 3 years of their establishment (A <20 cm, B >20 cm and C total soil profile)
Lines at the top of the columns represent standard error of mean
Columns annoted with the same lowercase letter are not significantly different within each soil depth class at p<0.05

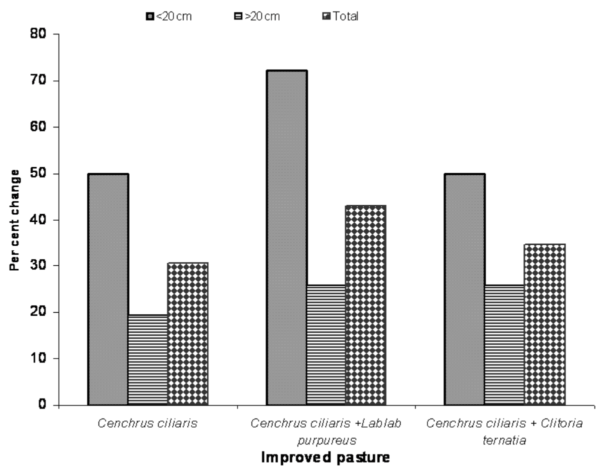

Fig. 2. Per cent change in soil organic carbon in the interdunal soils under different improved pastures over the natural unmanaged pasture (calculated from the mean values)

ciliaris + *C. ternatia*, respectively. The SOC under the *C. ciliaris* + *L. purpureus* was highest and significantly different from the all other pastures. However, unlike plow layer, SOC under *C. ciliaris* and *C. ciliaris* + *C. ternatia* were not significantly different. In all the improved pastures, there was significantly higher SOC over the natural pasture considering 100 cm soil profile.

Per cent change in SOC under improved pastures of grass and legumes over the natural unmanaged pasture (Figure 3) suggested that combination of *L. purpureus* and *C. ciliaris* had the highest impact on soil organic carbon in the plow layer over *C. ciliaris* alone or the *C. ciliaris* with *C. ternatia*. *C. ciliaris* + *L. purpureus* pasture led to 72.2 % increase in SOC in plow layer over natural pasture as compared to 50 per cent increase in both the *C. ciliaris* alone and *C. ciliaris* + *C. ternatia*. It indicated the highest impact of *C. ciliaris* + *L. purpureus* on the SOC in plow layer. However, Change in SOC in the sub-surface layers under both the combinations of *C. ciliaris* +*L. purpureus* and *C. ciliaris*+ *Clitoria ternatia* were the same (25.8%) over the natural pasture. Change in SOC in the soil profile over natural pasture was highest under *C. ciliaris* + *L purpureus* (42.8 %) which was followed by *C. ciliaris* + *C. ternatia* (34.6%) and *C. ciliaris* alone (30.6%).

Proportion of soil organic carbon added in plow and sub-surface layers in the soils of the improved pastures (Figure 4) was varying with the type of improved pastures. Of the total SOC added in case of sole *C. ciliaris*, about 60% was added in the surface and 40 % in the sub-surface layers. Presence of forage legumes led to more SOC build-up in sub-surface as compared to plow layers. About 59.2 % of total SOC in case of *C. ciliaris* + *L. purpureus* was in the surface and 40.8% in the sub-surface layers. The highest proportion of SOC was observed with *C. ciliaris* + *C. ternatia* in the sub- surface as 48.44% and 51.56 % in the surface layers. Therefore, it is the characteristics of the legume root biomass, which regulated the SOC in the different layers. Two observations were clearly made with the study. Firstly, introduction of the improved pastures in place of natural pastures had significant impact on the SOC of the soil after 3 years at not only in the plow layer but also in the sub-surface layer and secondly, the amount of SOC varied with the type of the pasture

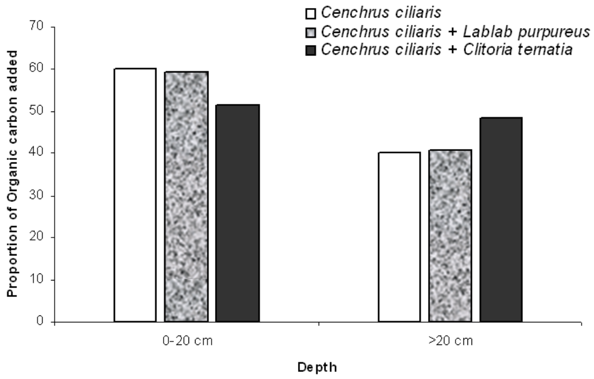

Fig. 3. Proportion of soil organic carbon added in the different layers of soil due to introduction of improved pastures of grass and forage legumes

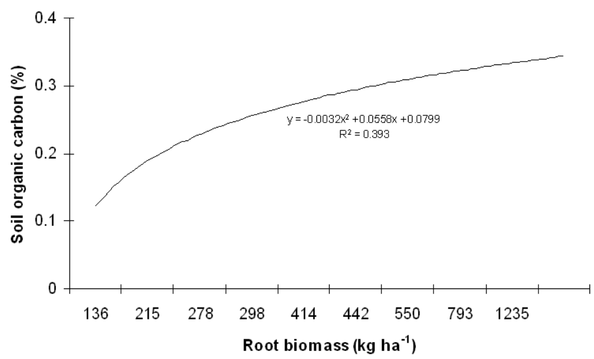

Fig. 4. Relation between Added root biomass and soil organic carbon (pooled data from both plow and sub-surface layers)

species. Similarly, root biomass was also increased under improved pastures.

Natural unmanaged pasture showed constantly lowest biomass yield over other improved pastures. Further, intercropping of *ciliaris* + *L. purpureus* and *C. ciliaris* + *C. ternatia* produced significantly higher shoot and root biomass than the sole *C. ciliaris*. Dwiwedi and Kumar (1999) and Graham et al (1986) also reported that the combination of *C. ciliaris* with *L. purpureus* and *C. ternatia* legumes increased the shoot biomass yield over the sole *C. ciliaris*. Increased biomass of grass and legume combination in our experiment indicated the niche separation for both the components that is of potential agricultural significance as a means of obtaining higher yield than monoculture. Increase yields of mixtures tended to rest on the different depths (Wilson, 1988). Root density was highest in the *C. ciliaris* + *C. ternatia in* the plow, sub- surface and in total soil profile, which was followed by the *C. ciliaris* + *L. purpureus*, *C. ciliaris* alone and natural pasture. Presence of low quantity of root per unit soil volume under the natural pasture leaves lesser opportunity for the soil microflora for residue decomposition and thus conversion of residues to the soil organic carbon. Whereas in case of improved pastures of *C. ciliaris*, *C. ciliaris* + *L. purpureus* and *C. ciliaris* + *C. ternatia* produced more root biomass per unit volume of the soil and thus renders better opportunity for the soil microflora for the decomposition of residues. Rao and Box (1998) reported that the nutrients cycling and carbon sequestration in soil occurs at significant levels *via* root turn over of sown tropical pastures under grazing. Dense and prolific root system had positive effect on soil organic carbon (Balesdent and Balbane, 1996). Higher root density (Table 3) under sub-surface soil in case of *C. ciliaris* + *L. purpureus* (34.5 g/m^2), *C. ciliaris* + *C. ternatia* (83.40 g/m^2) and sole *C. ciliaris* (22.2 g/m^2) over natural pasture (9.2 g/m^2) in case of this experiment also supports this view.

Under natural unmanaged field, SOC was almost un-affected both in the plow and sub-surface layers after a period of 3 years. In many unmanaged grassland ecosystems, which are characterized by non-equilibrium dynamics, the relative importance and limitation of different plant resources changes greatly over space and time (Knapp et al., 1998) and thus, the impact of natural grassland species on soil organic carbon likely to vary considerably spatially and from year to year. This situation ultimately indicated no change in the soil organic carbon in the soil under natural vegetation cover. On the other hand, introduction of improved pastures of grass and forage legumes increased the soil organic carbon at both plow and sub-surface layer as compared to the natural pasture Mendham et al (2003).

It was clearly observed the addition of soil organic carbon under the improved pasture of *C. ciliaris* + *L. purpureus* indicated that whatever the additional soil carbon was observed, it was derived from the crop residues, particularly of plant roots. On the other hand, relatively lesser organic carbon in case of *C. ciliaris* + *C. ternatia* in spite of the fact that more root biomass was added under this pasture support this view that characteristics of the residues play main role in the soil organic matter formation (Fig. 6). C: N ratio of pasture species found variable. *C. ciliaris* roots and shoots contained lower C: N ratio than natural pasture species, but higher than both *L. purpureus* and *C. ternatia*. *C. ciliaris* grown in the mixed pastures with legumes showed lowering of C: N ratio both in shoots and roots. C: N ratio of *L. purpureus* was lowest (45.2 for roots and 47.7 shoots). *C. ternatia* showed lower C: N ratio than *C. ciliaris* but more than *L. purpureus*.

L. purpureus nodulated profusely (Tripathi and Garg, 2003) under field conditions. About 15-21 nodules $plant^{-1}$ with 370.6-401.9 g fresh weight per plant whereas, during all three years very poor nodulation was recorded in case of *C. ternatia* about 3-7 nodules $plant^{-1}$ with 58.7-145.1 g fresh weight per plant. This situation might result in lower C: N ratios of *L. purpureus* residues that might have favored their decomposition and thus conversion to the soil organic carbon. Under the present study, the types of organic residues entering the soil were variable due to their characteristics and composition. In turn amount of nitrogen entering the soil through pasture legumes will largely dependent on the composition of pasture legume, thus influencing the total C: N ratio in soil and the rate of incorporation of mineral organic carbon into the soil matrix.

Root residue decomposition studies (Table 4) in the laboratory suggested that addition of grass root residues in the soil led to highest release of CO_2 (70.2 µg/g /h). Mixing of grass roots with legume roots led to decrease in CO_2 release by 29.05 and 21.50% respectively, under mixtures of *C. ciliaris* + *L. purpureus* and *C. ciliaris* + *C. ternatia*. On the other hand, microbial biomass carbon in the same soil showed highest microbial biomass carbon with *C. ciliaris* + *L. purpureus* (375.1 µg/g soil) followed by *C. ciliaris* + *C. ternatia* (364.8 µg/g soil) and C. ciliaris alone (310.6 µg/g soil). This indicated that presence of *L. purpureus* and *C. ternatia* in the grass field reduce the carbon oxidation and at the same time divert more soil carbon towards the soil microbial biomass. The larger size and specific activity of the soil microbial biomass in the mixed treatments of grass and legume suggested a stimulating effect of the two plant species on substrate utilization of microbial activity and therefore converting more crop residues into soil organic carbon (Neergard et al., 2004). Proper coverage of soil under the legume and grass combination during the dry season might have good impact on soil organic carbon build- up (Baschiazzo et al., 1999). Improvement in soil organic carbon by cover crops of legumes was mainly related to speed of ground covering and sub- soil root density (Huluggalle 1988).

Table 4. Effect of grass legume residue mixing on the residue decomposition and microbial biomass carbon (after 43 weeks) in a laboratory incubation experiment (mean of 3 samples)

Pasture	Cumulative CO_2 released (µg/g/hr)	Microbial biomass carbon (µg g^{-1} soil)
Control	21.4	194.3
C. ciliaris	70.2	310.6
C. ciliaris + *L. purpureus*	49.8	375.1
C. ciliaris + *C. ternatia*	45.1	364.8

Figure 4 describes the relation between root biomass added in the soil and the soil organic carbon. Regression coefficient (R^2 0.39) for the line SOC = -0.0032 (root biomass $)^2$ + 0.0558 root biomass + 0.0799 clearly revealed the positive correlation between soil organic carbon build-up and the root biomass

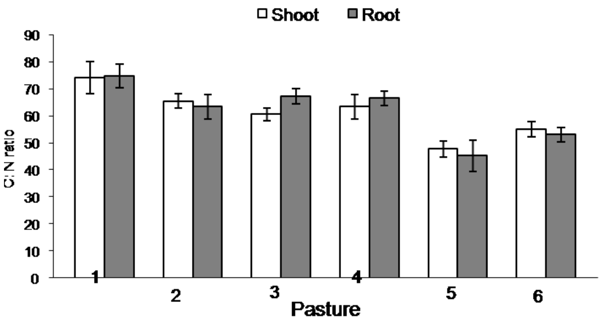

Fig. 5. C: N ratio of different pasture species in shoot and root
1. Natural pasture, 2. *C. ciliaris* (pure), 3. *C. ciliaris* (with *L. purpureus*, 4. *C. ciliaris* (with *C. ternatia*), 5. *L. purpureus (*with *C. ciliaris*), 6. *C. ternatia (with C. ciliaris)*

added in the soil. This increase in SOC was upto a limit, beyond that addition of root biomass had relatively less effect on SOC. Therefore, more root biomass is added in the soil led to increased SOC build-up. But absence of significant regression coefficient under the present study clearly pointed out that the quantity of root biomass was not the only determining factor for conversion of residues in the soil organic carbon. It is the quality of the residues and soil environment played major role in the conversion of residues to the soil organic carbon. Under the present study, maximum root biomass was added in the soils of *C. ciliaris* + *C. ternatia* pasture. But, the maximum build up was observed in the soils under the pasture of *C. ciliaris* + *L. purpureus*. This is the matter of future line of the research.

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INTEGRATING CROP AND RESOURCE MANAGEMENT TECHNOLOGIES FOR ENHANCED PRODUCTIVITY, PROFITABILITY, AND SUSTAINABILITY OF THE VEGETABLE BASED CROPPING SYSTEM IN NORTH WEST INDIA

R.K. Naresh[1], Raj K. Gupta[2], Prem Singh[3], B. Singh[4], Ashok Kumar[5], A.K. Misra[6], Gajendra Pal[7], P.K. Singh[7] and Madhvendra Singh[8]

Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut-250 110

Abstract

Agricultural diversification towards high-value crops can potentially increase farm incomes, especially in a country like India where demand for high-value food products has been increasing more quickly than that for staple crops. Indian agriculture is overwhelmingly dominated by smallholders, and researchers have long debated the ability of a smallholder-dominated subsistence farm economy to diversify into riskier high-value crops. Here, we present evidence that the gradual diversification of Indian agriculture towards high-value crops exhibits a pro-smallholder bias, with smallholders playing a proportionally larger role in the cultivation of vegetables. The observed patterns are consistent with simple comparative advantage-based production choices. The comparatively high labor endowments of the small farmers, as reflected in their greater family sizes, induce them to diversify towards vegetables. Furthermore, the probability of participation in vegetable cultivation as well as land allocation to horticulture decreases with the size of landholdings in India. Small or medium holders do not appear to allocate a greater share of land to vegetables. However, the share allocated to vegetables is significantly higher if the family size is bigger. India is the second largest producer of vegetables in the world but at the same time it does not produce that amount of vegetables, which can meet the daily requirement of an individual in India. Efforts are on to increase the production of vegetable crops at the national level. It is noticed in a report of Indian Council of Agricultural Research (ICAR-2002) that the present production of 90.8 million tones is to be raised to 250 million tones by 2024-2025. The Government efforts are noteworthy to produce the substantial amount of vegetables so that the target could be achieved. The major noticeable efforts are bringing additional area under vegetable crops, using hybrid seeds and use of improved agro-techniques. Another potential approach is perfection and promotion of protected cultivation of vegetables (Singh, 1998; Singh *et al.*, 1999).

In a project supported by theUPCAR, a number of improved land and crop management practices, often termed resource-conserving technologies (RCTs), have successfully been developed and disseminated in the North West India.Among the RCTs, the most popular are laser land leveling, zero- and reduced-till drill-seeded Vegetables, direct seeding of cabbage. The vast majority of farmers have adopted them because of increased productivity, reduced costs, and higher profitability. The use of individual technologies did improve productivity and profitability to a certain extent, but combining and simultaneously applying a number of compatible RCTs is crucial for maximizing the overall benefits to farmers. Farmers generally integrated the new technologies into the portfolio of their own technologies already being practiced on their farms. This process

Corresponding author: [1]Department of Agronomy; [4]Department of Horticulture; [5]Department of Soil Science; [6]Krishi Vigyan Kendra, Saharanpur; [7]Directorate of Extension; [8]Krishi Vigyan Kendra,Ghaziabad, Sardar Vallabhbhai Patel University of Agriculture& Technology, Meerut-250110 (U. P.); [2] CIMMYT India office, NASC complex, Todapur road, Pusa, New Delhi-110012; [3]Project Directorate of Farming System System Research,Modipuram,Meerut-250110

of integrating new RCTs into an existing portfolio of technologies can be called integrated crop and resource management (ICRM). Being highly dynamic, ICRM will accept innovations as and when they become available. A good example of ICRM is the combined use of precision land leveling and drill seeding together with a full package of crop management to maximize system efficiency, productivity, and benefit. Additionally, some RCTs under ICRM have had positive effects on resource use and environmental quality. However, the adoption rates of ICRM with new RCTs were highly variable .This is because of variations across the North West India in vegetable system characteristics such as (1) agroclimatic conditions and land types; (2) farmers' knowledge, skills, resource endowments, and cultivation practices; (3) the time of introduction of ICRM with new RCTs and the extent of farmers' exposure to them; and (4) the amount of institutional and policy support to farmers. The key factors affecting the adoption of ICRM with new technologies by farmers and suggested strategies to facilitate wide adoption are discussed in this paper. The need continues to be to develop an effective program for wider evaluation, refinement, and dissemination of proven RCTs within the framework of ICRM for deprived farming communities,to realize their great impact on food security and farmers' livelihood in North West India.

Key words: conservation agriculture, differential technology adoption,livelihood, food security, integrated crop and resource management, resource-conserving technologies

In 2008, world food prices rose to levels that had not been seen for decades. Nominal prices of major food commodities reached their highest levels in nearly 50 years while prices in real terms were the highest in nearly 30 years (FAO 2008). Short-term reasons were extreme weather, depletion of grain stocks, speculation, diversion of food crops for bio-fuels, and the skyrocketing cost of energy and fertilizer. Behind these are longer-term trends: changes in the structure of food demand in rapidly growing developing economies, sluggish growth in cereal yields, emerging scarcity of agricultural water, continuing land degradation, and the unfolding effects of climate change and decreasing investments in agricultural R&D. Taken together, these factors suggest that high prices will be with us for years to come.

Rising food prices in North West India devastate poor consumers. The region is home to a large number of urban and rural poor whose diet is centered on cereals and who spend a large proportion of their income on food. In India, the poorest 20% spend 62% of their income on food, mostly rice and wheat. In Bangladesh, the poorest 20% spend 69% of their income on food, with rice accounting for 38% of the total (ADB 2008). Higher food prices drive more people into poverty and increase the distress among those who are already poor. Higher prices are catastrophic for rural and urban women because they must manage household activities and raise children.

Malnutrition continues to be widespread inNorth West India, a problem likely to worsen as food becomes more expensive. Even before the recent spike in food prices, child malnutrition was worse in South Asia than in sub-Saharan Africa. In the late 1990s, the proportion of children under five underweight for their age ranged from 38% to 48% in South Asia compared with 21% to 28% in selected African countries. The percent of infants with low birth weight ranged from 19% to 30% in South Asia compared with 11–17% in Africa. Since then, the situation is likely to have deteriorated in both regions (UNDP 2004).

Although agriculture occupies a shrinking share of India's national economy, achieving rapid growth in agriculture remains a major policy concern nationwide. The contribution of agriculture to India's gross domestic product (GDP) fell from 40% in 1980/81 to 21% in 2004/05. However, 72% of India's population lives in rural areas, and three-fourths of the people making up these rural populations depend on agriculture and allied activities for their livelihoods. Furthermore, the agricultural sector is the main source of employment in India, comprising 57% of the country's labor force in 1999/2000.

Between 1980/81 and 1995/96, the agricultural sector in India grew at a rate of 3.3% per year, and this growth had a significant impact on poverty reduction. This is consistent with the findings of Ravallion and Datt (1996) and Warr (2003), who showed that growth in the agricultural sector is more poverty-reducing than growth in other economic sectors. However, despite the past growth in this sector,agriculture in India is now beset with problems. Most importantly, agricultural growth decelerated to 2.1% between 1996/97 and 2002/03, largely due to a decline in the food grain segment that grew at merely 0.6%. Given the high dependence of the poor on agriculture, the stagnation in this sector is currently threatening to stall poverty reduction in India.

Under such a scenario, the fundamental question is: how can agricultural growth be accelerated? The potential to increase growth through staples appears limited, mainly because the demand for staples has stagnated. The consumption patterns have diversified towards high-value agricultural commodities (HVA) such as fruits, vegetables, dairy, poultry, fish, and processed food (Ravi and Roy 2006). This demand shift is underpinned by sustained income growth and urbanization; Ravi and Roy (2006) project demand in India through 2020, and show that the diversification in consumption patterns towards highvalue agricultural products will become more pronounced with income growth and changes in other determinants such as urbanization. Moreover, globalization has created new opportunities for the export of high-value products. Diaz-Bonilla and Recca (2000) observed an accelerated flow of exports of highvalue food commodities from developing to developed countries.

From the perspective of poverty reduction, diversification is particularly appealing. Most highvalue food commodities are labor-intensive, have low gestation periods and generate quick returns. Hence, they offer a perfect opportunity for smallholders to utilize surplus labor and augment their incomes (Joshi et al. 2002; Barghouti et al. 2005; Weinberger and Lumpkin, 2005). Previous studies in South and Southeast Asia have indicated that diversification towards high-value food commodities supports the development of innovative supply chains and opens new vistas for augmenting income, generating employment and promoting exports (Barghouti et al. 2004; Pingali 2004; Deshingkar et al. 2003; Pokharel 2003; Wickramasinghe et al. 2003; Goletti 1999). Moreover, food and income security have been shown to increase in regions where agricultural diversification takes place, particularly favoring horticulture, animal husbandry, and aquaculture (Barghouti et al. 2005; Dorjee et al. 2002).

However, the transition towards high-value agriculture is not without constraints, especially for smallholders. If the high-value commodities are products that the farmers have not grown before, the farmers may lack necessary information on production methods, marketing opportunities, and the probable distribution of net returns. This problem is particularly acute when the target consumers have very specific quality requirements and/or strict food safety requirements. Of course, the farmers can attempt to gather information, but this often involves a fixed cost (one not related to the level of output), thus giving an advantage to larger-scale farmers (Minot and Roy, 2006). Larger farmers are often better able to bear the risks associated with producing and marketing high-value commodities.

Furthermore, a small farmer who allocates land to a commercial crop often has to depend on market purchases to meet food requirements, resulting in an additional source of risk. Some high-value agricultural commodities also require significant investments, including the use of specific inputs. For example, fruit production typically means that the farmer must plant trees and wait 3-5 years for them to begin producing. Finally, the production and marketing of highly perishable high-value commodities benefit from the producing farm being located near markets and good marketing infrastructure (Torero and Gulati, 2004).

Farmers in developing countries such as India, particularly poor farmers, often do not have the savings or credit access needed to make these investments and purchase the necessary inputs. However, high-value commodities like fruits and vegetables may become viable prospects when these constraints are relieved through intervention. Furthermore, smallholders tend to have greater labor endowments (i.e.larger families), meaning that they may be better suited in cultivating labor intensive high-value crops.The competitiveness of small farmers relative to large farmers is not fixed and can change over time, usually as a result of changes in physical, human, or social capital. Farmers may acquire new equipment or build irrigation works (physical capital) that reduce the cost of production. Farmer skills (human capital) can also change over time as a result of learning-by-doing and/or through outside technical assistance (Minot and Roy, 2006).There has been some debate as to whether a smallholder-dominated economy can actually diversify, and whether smallholders participate significantly in production diversification towards highvalue products. Here, we use both aggregate and household-level data to address this question in the context of crop diversification towards fruits and vegetables in India. The time period for the state-level analysis spans more than two decades, from 1980/81 to 2002/03.

During this period, India became self-sufficient in grain production (during the 1990s), which might have triggered diversification out of staples. Also, the food basket of consumers underwent a significant change during the 1990s; the per capita consumption of cereals declined, while that of highvalue commodities increased considerably. Moreover, India initiated economic reforms in 1991. Since then, a number of policy initiatives have been undertaken to liberalize markets and improve agricultureindustry linkages. A priori, it is expected that these developments played a role in inducing diversification.Using state-level information on the percentage of landholdings belonging to smallholders, along with various indicators of diversification in agriculture, we show that diversification away from cereals into fruits and vegetables is significantly higher in states with a greater share of smallholders. Our fixed effects specification suggests that these results are robust after controlling for observed and unobserved state level factors.

Further, using household-level data for a single time period, we assess crop choices across the various farm sizes and show that the probability of a given household diversifying into vegetable cultivation is higher for smaller farmers, but that no such bias exists in the case of fruits. This can likely be explained by the relatively lower labor requirements and greater capital intensity (in terms of both start-up and working capital) required for cultivation of fruits, both of which work against small farmers.Larger families show a higher tendency to diversify mainly into vegetables, whereas family size does not significantly impact diversification into fruits. Finally, in vegetables, the probability of diversifying into the respective commodity declines with increasing land size.

Integrated crop and resource management for enhancing productivity and resource use

Various terms have been coined to integrate different technologies that result in increased (1) crop productivity, (2) profitability, (3) resource-use efficiency, and (4)resource conservation. These are integrated crop management (ICM), integrated rice management (IRM), integrated natural resource management (INRM), and conservation agriculture (CA). Although these terms are popularly used, none seems to clearly reflect the above four aspects of system performance in an integrated manner. We propose integrated crop and resource management (ICRM), which intuitively includes two components: (1) crop management (CM) combining a number of compatible crop production technologies to enhance crop yields and profitability with optimum external inputs, and (2) natural resource management (NRM), which deals with the conservation and efficient use of natural resources such as soil, water, flora and fauna species (biodiversity), and other biological resources. In fact, RCTs can be viewed as the key elements of ICRM.

At a practical or field level, the two components of ICRM (CM and NRM) are inseparable; they together promote the conservation and good management of natural resources for high crop productivity. In a way, the concept of ICRM also follows the approach of CA. The goals of CA are to conserve, improve, and make more efficient use of natural resources through integrated management of soil, water, crop varieties and animal species, and other biological resources. In the long run, CA contributes to both enhanced productivity and environmental conservation on a sustainable basis. Elements of CA include minimum soil disturbance, permanent organic soil cover (crop residues), and appropriate and economic crop rotations to sustain crop yields and prevent disease and pest problems (FAO 2007, Hobbs et al 2008). CA thus promotes minimum disturbance of soil by zero- or reduced tillage, balanced and crop-based application of chemical inputs, and skillful management of crop residues and wastes (Dumanski et al 2006). In the final analysis, ICRM is more or less akin to CA, which allows the integration of various RCTs into farmers' portfolio of technologies to enhance the total productivity, profitability, and environmental quality of any cropping or farming system (e.g., the vegetable system). The aim of this paper is to describe the ICRM for Integrating crop and resource management technologies for enhanced productivity, profitability, and sustainability of the vegetable system in North West India.

MATERIALS & METHODS

Two set of experiments on different tillage and crop establishment techniques involving permanent beds were conducted under researcher managed trials at the research farm ($29^0 01'$ N, $77^0 45'$ E, and 237 m above mean sea level) of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (Uttar Pradesh), India, and farmer managed trials in Ghaziabad & Saharanpur district of Uttar Pradesh in western Gangetic Plain during 2008 & 2009. The water table depth of the experimental sites is 23 m with very good quality of water. The climate of the area is semiarid, with an average annual rainfall of 805 mm (75–80% of which is received during July to September), minimum temperature of 0 to 4^{0}C in January, maximum temperature of 41 to 45^{0}C in June, and relative humidity of 67 to 83% throughout the year.The experimental soil (0–15 cm) was silty loam in texture, with a bulk density of 1.48 Mg m^{-3}, weighted mean diameter of soil aggregates 0.74 mm, pH =7.9, total C = 8.3 g kg^{-1}, total N = 0.83 g kg^{-1}, Olsen P = 28 mg kg^{-1}, and K = 128 mg kg^{-1}.

Experiment –I: The experiment was initiated during monsoon 2008 at SVPUAT, Meerut research farm involving permanent beds systems in cabbage-capsicum –cowpea rotation. A randomized block design (RBD) was used in the study. A combination of six tillage and crop establishment techniques [**1.** direct seeded on narrow beds (DS N Bed)**2.**transplanted on narrow beds (TP N Bed) **3.** direct seeded on wide beds (DS W Bed) **4.** Transplanted on wide beds (TP W Bed) **5.**direct seeded on flat beds (DS F Bed) **6.**transplanted on flat beds (TP F Bed) along with rice residues (+R) in Cabbage. The changes in soil physical properties were recorded using standard techniques. The soil samples were taken at 0-15 cm soil layer from top of the beds in permanent beds and within the row in flats. The details of the treatments are as follows-

Direct seeded Cabbage on narrow raised beds and direct seeded Cowpea & transplanted Capsicum on permanent narrow raised beds :

Cabbage (DSNBed): At the beginning of the experiment soil was tilled by three harrowings and three plowings followed by one field leveling with a wooden plank, and raised beds were made using a tractor-drawn multi crop zero till cum raised bed planter with enclined plate

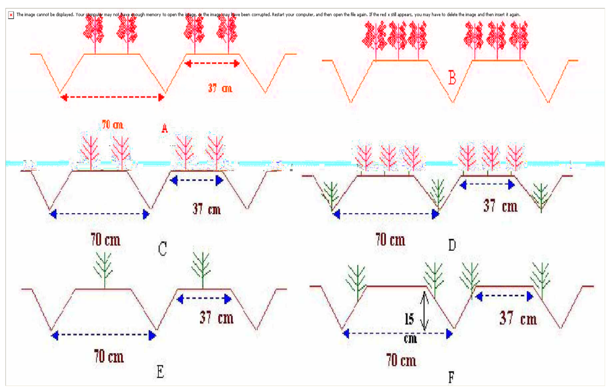

Fig 1(a): A-Two rows of cauliflower on top of the beds, B- One row of brinjal in the centre of the bed & two rows of corriander, C- Two rows of carrot on the top of the beds, D- Three rows of direct seeding of cabbage on the top of beds and one row of sugarcane in furrow, E- One row of brinjal on top of the beds, F- Two rows of okra on the slope of the beds.

seed metering devices. The dimension of the narrow beds were 37 cm wide (top of the bed) x 15 cm height x 30 cm furrow width (at top) and the spacing from centre of the furrow to another centre of the furrow was kept at 67 cm(fig.1(a).

Two rows of cabbage were direct-seeded on each raised bed at 30-cm row-to-row spacing on the same day of nursery sowing for transplanting . The raised beds were seeded using a bed planter, which placed seeds and fertilizer simultaneouslyThe first irrigation was applied at 1 day after seeding(DAS), followed by alternate days irrigations for 1 week for germination to maintain soil saturation. Subsequent irrigations (5±2 cm) were given at 60% field capacity depending on the rainfall at critical stages.

Cowpea(DSNBed): After cabbage,two rows of cowpea was seeded directly after reshaping the beds using a multi crop zero till cum raised bed planter with enclined plate seed metering devices without any preparatory tillage. The irrigation was applied just after sowing following second irrigation 7 days after first irrigation and the Subsequent irrigations (5±2 cm) were given at 60% field capacity depending on rainfall.

Capsicum (TPNBed): After cowpea beds were reshaped for brinjal, slits were opened using zero till cum ferti -seed drill with enclined plate metering system in dry conditions and in one row of brinjal transplanting was done in the open slits with 50- by 50-cm spacing between plants. The irrigation was applied just after transplanting following second irrigation 3 days after first irrigation and the Subsequent irrigations (5±2 cm) were given at 60% field capacity depending on rainfall.

Transplanted Cabbage on narrow raised beds and direct seeded cowpea & transplanted capsicum on permanent narrow raised beds:

Cabbage (TPNBed): At the beginning of the experiment soil was tilled by three harrowings and three plowings followed by one field leveling with a wooden plank, and raised beds were made using a tractor-drawn multi crop zero till cum raised bed planter with enclined plate seed metering devices. The dimension of the narrow beds were 37 cm wide (top of the bed) x 15 cm height x 30 cm furrow width (at top) and the spacing from centre of the furrow to another centre of the furrow was kept at 67 cm. For cabbage, slits were opened using zero till cum ferti -seed drill with enclined plate metering system in dry conditions and in two rows of cabbage transplanting was done in the open slits with 20 by 20cm spacing between plants. The irrigation was applied just after transplanting following second irrigation 2 days after first irrigation and the Subsequent irrigations (5±2 cm) were given at 60% field capacity depending on rainfall.

Okra (DSNBed) and Brinjal(TPNBed) *:Similar as above*

Direct seeded Cabbage on wide raised beds and direct seeded cowpea & transplanted capsicum on permanent wide raised beds :

Cabbage (DSWBed): At the beginning of the experiment soil was tilled by three harrowings and three plowings followed by one field leveling with a wooden plank, and raised beds were made using a tractor-drawn multi crop zero till cum raised bed planter with enclined plate seed metering devices.The dimension of the wide beds were 120 cm wide (top of the bed) x 12 cm height x 30 cm furrow width (at top) and the spacing from centre of the furrow to another centre of the furrow was kept at 150 cm (fig 1(b). Four rows of cabbage were direct-seeded on each raised bed at 30-cm row-to-row spacing on the same day of nursery sowing for transplanting. The raised beds were seeded using a bed planter, which placed seeds and fertilizer simultaneously.The first irrigation was applied at 1 day after seeding(DAS), followed by alternate days irrigations for 1 week for germination to maintain soil saturation. Subsequent irrigations (5±2 cm) were given at 60% field capacity depending on the rainfall at critical stages.

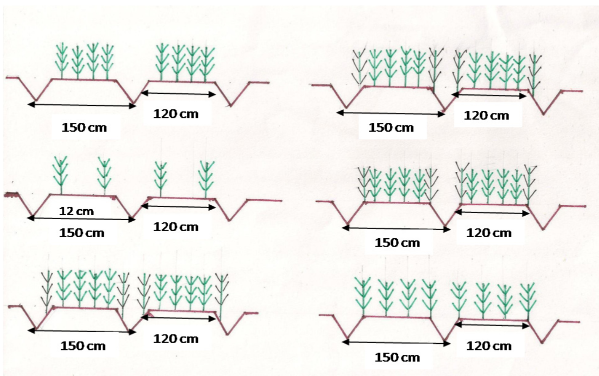

Fig 1(b) : A- Four rows of cabbage on top of the beds, B- Four rows of carrot on top of the beds and one row of tomato on shoulder of the bed, C- Two rows of brinjal on top of the beds, D- Four rows of cauliflower on top of the beds and one row of corriander on shoulder of the bed, E- Four rows of direct seeding of cabbage on top of the beds and sugarcane on the shoulder of the bed, F- Four rows of okra on top of the beds.

Cowpea (DSWBed): After cabbage,four rows of cowpea were seeded directly after reshaping the beds using a multi crop zero till cum raised bed planter with enclined plate seed metering devices without any preparatory tillage. The irrigation was applied just after sowing following second irrigation 7 days after first irrigation and the Subsequent irrigations (5±2 cm) were given at 60% field capacity depending on rainfall.

Capsicum (TPWBed): After cowpea beds were reshaped for capsicum, slits were opened using zero till cum ferti -seed drill with enclined plate metering system in dry conditions and on the shoulder of the bed transplanting was done in the open slits with 50- by 50-cm spacing between plants. The irrigation was applied just after transplanting following second irrigation 3 days after first irrigation and the Subsequent irrigations (5±2 cm) were given at 60% field capacity depending on rainfall.

Transplanted Cabbage on wide raised beds and direct seeded cowpea & transplanted capsicum on permanent wide raised beds:

Cabbage (TPWBed): At the beginning of the experiment soil was tilled by three harrowings and three plowings followed by one field leveling with a wooden plank, and raised beds were made using a tractor-drawn multi crop zero till cum raised bed planter with enclined plate seed metering devices. The dimension of the wide beds were 120 cm wide (top of the bed) x 12 cm height x 30 cm furrow width (at top) and the spacing from centre of the furrow to another centre of the furrow was kept at 150 cm. For cabbage, slits were opened using zero till cum ferti -seed drill with enclined plate metering system in dry conditions and four rows of cabbage transplanting was done in the open slits with 20 by 20cm spacing between plants.The irrigation was applied just after transplanting following second irrigation 2 days after first irrigation and the Subsequent irrigations (5±2 cm) were given at 60% field capacity depending on rainfall.

Cowpea (DSNBed) and Capsicum (TPNBed):*Similar as above*

Direct seeded Cabbage on flat beds and direct seeded cowpea & transplanted capsicum in zero tillage flat beds :

Cabbage (DSFBed): At the beginning of the experiment soil was tilled by three harrowings and three plowings followed by one field leveling with a wooden plank, and cabbage was direct-seeded in flat plots at 30-cm row spacing using a multi crop zero till cum raised bed planter with enclined plate seed metering devices. The seeding was done on the same day of nursery sowing for transplanting cabbage. The first irrigation was applied at 1 day after seeding(DAS), followed by alternate days irrigations for 1 week for germination to maintain soil saturation. Subsequent irrigations (5±2 cm) were given at 60% field capacity depending on the rainfall at critical stages.

Cowpea (DSFBed): After cabbage, cowpea crop was sown in rows 30 cm apart using multi crop zero till cum raised bed planter with enclined plate seed metering devices without any preparatory tillage. The irrigation was applied just after sowing following second irrigation 7days after first irrigation and the Subsequent irrigations (5±2 cm) were given at 60% field capacity depending on rainfall.

Capsicum(TPFBed): For capsicum, slits were opened with 50-by-50 cm row spacing using zero till cum ferti -seed drill with enclined plate metering system in dry conditions and transplanting was done in the open slits with 50- by 50-cm spacing between plants without any preparatory tillage. The irrigation was applied just after transplanting following second irrigation 3 days after first irrigation and the Subsequent irrigations (5±2 cm) were given at 60% field capacity depending on rainfall.

Transplanted Cabbage on flat beds and direct seeded Okra & transplanted Brinjal in zero tillage flat beds:

Cabbage (TPFBed): At the beginning of the experiment soil was tilled by three harrowings and three plowings followed by one field leveling with a wooden plank, and for cabbage slits were opened with 30-by-30 cm row spacing using zero till cum ferti -seed drill with enclined plate metering system in dry conditions and transplanting was done in the open slits with 30- by 30-cm spacing between plants.The irrigation was applied just after transplanting following second irrigation 2 days after first irrigation and the Subsequent irrigations (5±2 cm) were given at 60% field capacity depending on rainfall.

Cowpea (DSNBed) and Capsicum (TPNBed): *Similar as above*

Crop residue management: The rice residue was managed at 6.0 t ha^{-1} (partially anchored and partially loose).

Experiment-II: The farmers' participatory trials was initiated during monsoon 2008 on tillage and crop establishment techniques at five locations (one farmer at each location) in Ghaziabad & Saharanpur district for two years on cauliflower-carrot crop.Three tillage and crop establishment techniques [1.direct seeded/transplanted on narrow beds (DS/TP N Bed),2. Direct seeded/transplanted on wide beds (DS/TP W Bed),3. Direct seeded/transplanted on flat beds (DS/TP F Bed) along with rice residues (+R) in Cauliflower and other vegetable crops.Each farmer was considered as one replication and data was analysed using randomized block design(RBD).

Results & Discussion

Approach

While evolving technologies, we may have to seek participation of farmers at every stage of technology development starting from conceiving the idea, articulating the way it will be accepted, inviting the partners who can help outsourcing technical inputs, demonstrating the technology and marketing at the same time. Squeezing lots of components in any candidate technology at farmers' field is not easy. Technologies leading to conservation agriculture can be evolved in bottom-up mechanism between scientists and the farmers. The evolution of technologies,

Urbanisation is happening with housing and manufacturing now competing with agriculture. It means we will have to make multiple use of our land to compensate for the land going to other sectors.

therefore, rests as much on its farmers as its scientists. Experience has shown that farmers alwayslove new technologies and they also love to try new things. It is, therefore, necessary to developtechnologies which are demand driven. Instead of perfecting a technology behind the fore walls of research station, they should be perfected at farmers' fields. Many of our peers do not respond and it is always hardest thing to do. Innovations are driven by leaders and collaboration. Getting all of them towards the end objective is important. It has to be farmers centric. Farmers centric do not mean a passive group of farmers. It means that we have to target certain individuals who then spread and confirm or negate the virtues of any new technology that we evolve and accelerate. The success is then based on the word of mouth as a personal example. The evolution of technologies like furrow irrigated raised bed is explicitly based on such social interactions which are more effective to further accelerate the process of adoption. This process adopted by **Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut-250110 U.P.,India,** has not only made it easy to evolve and accept furrow irrigated raised bed in India but also helped transferring this technology across borders including Pakistan and Nepal.The process itself has given better access to farmers to technology and that is why it has diffused across borders. The successful evolution and accelerated adoption of resource conservation technologies in vegetable cropping system using the model of farmer's participatory approach represents a significant shift both in ways agriculture scientists think about resource conservation to sustain agriculture growth and how they think about investigating in it. Policy makers and other stakeholders including farmers stand to gain from this approach. These technologies are being introduced not only to boost the profits of farmers but also to reduce the long-term harmful effect of decrease in soil health and decline in water table. This approach has accelerated the adoption process of some technologies like furrow irrigated raised bed, multiple land use, inter-seeding of wheat, mustard,onion and garlic on beds with autumn planting of sugarcane in furrows, intrusion of extra short duration summer moong to displace summer rice, laser land levelling, evolution of zero-tillage in transplanted rice using paddy transplanter and direct seeded rice. In contrast to 5-6 years it takes to generate new recommendations using conventional approach, the farmer's participatory approach takes 2-3 years. During last 10 years, the network of scientists from National Agricultural Research System and from International Agricultural Research System has created insight into number of resource conserving technologies. More than that their quality research is demonstrated by accelerated acceptance by farmers, has made the difference as to how some researches need to be conducted.

ADVENT OF RESOURCE CONSERVING TECHNOLOGIES

Another important factor that may enhance the diversification of rice-wheat systems is the new "platform" made possible by the recent advent of resource conserving technologies in the Western Indo-Gangetic Plains. There has been extensive on-station and on-farm testing and adaptation of a range of technologies, including zero-tillage and direct seeding of cereal crops such as wheat and bed planting. This implied investments for designing local, effective, and affordable seeding equipment as the successful adoption of the technology depends on farmer knowledge and machinery availability. zero tillage and significantly reduced tillage is now practiced on over 3 million hectares- from just 5000 hectares in 2000. This technology is primarily applied to wheat and has reduced the cost of cultivation by Rs 3000/-per ha by lowering land preparation costs and thus increased farmer incomes. The underlying saving of 70 liters of diesel per ha also curbs the release of CO_2 to the atmosphere. The adoption of this technology produced an additional 0.5 million tons of wheat primarily due to more timely planting, and also saved a foreign exchange of Rs 4050 crores through reduced fuel consumption in tillage and irrigation operations. The success with reducing tillage in wheat implies a significant first step in moving the rice- wheat systems towards conservation agriculture. Through farmers managed trials scientists are currently addressing some of the remaining challenges, including the need to diversify the prevailing rice-wheat rotation.

Research Efforts and Strategy

Any technology for its wider dissemination should fit in farmer's own scheme of things. It should adapt to his agro-ecological matrix. So, instead of testing the technology in smaller plots at research station, farmer participatory approach was adopted with twin methodologies :

(i) Those farmers who are already doing intercropping in one or the other way were encouraged to have the sugarcane based intercropping system under furrow irrigated raised bed system.

(ii) Those farmers going for post wheat planting of sugarcane in the month of May were introduced to autumn planting of sugarcane + wheat in FIRBS system.

(iii) In addition to this, the concept of vegetables as intercrops was tried in those cases where farmers were growing vegetables and sugarcane as sole crop.

NEW TECHNOLOGICAL OPTIONS FOR HORTICULTURAL DIVERSIFICATION

In the context of diversification, the debate has always focused on what areas, in which season, and how to diversify. Farmers need to consider the yields in respective areas and cropping seasons keeping in mind how to relocate the more remunerative crops over large areas to generate employment and foster food security and health for all. Intensification through relay cropping and intercropping is an option for promoting diversification.Appropriate tillage and cultivar choices are currently being tried with farmers in their fields and can lead to high system productivity in the risk free winter summer season in the western plains. With some groundwater development and relocation of *Turmeric* to irrigated areas in midlands and uplands, new crop sequences can be introduced into the lowlands, sequences that include short duration direct-seeded cabbage, potato, winter maize, legumes, oilseeds and vegetables.

Permanent raised-bed planting provides additional options in Western Indo-Gangetic Plains to generate alternate sources of productivity growth in vegetable crops and through intercropping of autumn planted crop. For example, Coriander is an optional intercrop with wheat on wide raised beds. Wheat is planted in November and Coriander crop slips are sown on the shoulders of the furrows by the end of January. Farmers get an additional income of nearly Rs 72000 ha^{-1} through sale of the coriander for leafy spices. It has also been reported by several farmers that since coriander requires irrigation when wheat crop is maturing, it helps dissipate heat and offset the adverse effects of the rise in average minimum temperature during grain filling.

Intercropping of sugarcane with potato, vegetable and garden pea/french bean followed by *Turmeric* has the potential in the western Ganges not only to intensify the rice-wheat system but also to diversify it through crop substitutions. Surface seeding is yet another crop establishment option that helps intensifying lands currently known as "rice fallows", and improves income for farmers that manage these lands. Many "rice-fallows" can be planted with direct seeded cabbage using surface seeding techniques in the western Plains and permanen raised beds controlled traffic technology in low lying areas and excessively moist soils can help manage

Table 1 : Productivity of cabbage, capsicum and cowpea crops under various tillage and establishment techniques.

Crop establishment	Yield t ha^{-1} Cabbage	Capsicum	Cowpea
DS N Bed +R	30.6	14.6	6.2
DS N Bed	28.4	11.3	5.1
TP N Bed +R	27.5	13.8	5.9
TP N Bed	25.7	10.9	4.9
DSW Bed +R	33.6	16.5	7.5
DSW Bed	31.7	12.8	6.4
TP W Bed +R	32.5	15.9	7.3
TP W Bed	30.6	11.7	6.1
DS F Bed +R	23.5	9.7	4.3
DS Fbed	22.7	8.5	3.9
TP FBed +R	21.5	9.3	4.1
TP Fbed	20.6	8.2	3.6
Average	27.41	11.93	5.44

DS N Bed +R- Direct seeded on narrow beds with residue, DS N Bed- Direct seeded on narrow beds, TP N Bed +R- Tranaplanted on narrow beds with residue, TP N Bed- Tranaplanted on narrow beds, DSWBed +R- Direct seeded on wide beds with residue, DSWBed- Direct seeded on wide beds, TPWBed +R- Tranaplanted on wide beds with residue, TP W Bed- Tranaplanted on wide beds, DSFBed +R- Direct seeded on flat beds with residue, DSFBed- Direct seeded on flat beds, TPFBed +R- Tranaplanted on flat beds with residue, TPFBed- Tranaplanted on flat beds.

Table 2 : water productivity and profitability of cabbage , capsicum and cowpea crops under various tillage and establishment techniques.

Crop establishment	Water productivity (kg yield m^{-3} water)			Net profit(Rs ha^{-1})		
	Cabbage	Capsicum	Cowpea	Cabbage	Capsicum	Cowpea
DS N Bed +R	8.743	3.074	2.531	54025	51550	34100
DS N Bed	7.889	2.329	2.040	50140	39900	28050
TP N Bed +R	7.237	2.816	2.269	48550	48725	32450
TP N Bed	6.346	2.193	1.815	45375	38470	26950
DSW Bed +R	10.667	4.783	3.488	59320	58265	41250
DSW Bed	9.606	3.556	2.844	55960	45200	35200
TP W Bed +R	9.701	4.356	3.042	57375	56125	40150
TP W Bed	8.743	3.039	2.440	53075	41325	33550
DS F Bed +R	5.663	1.921	1.365	41490	34250	23650
DS Fbed	5.341	1.619	1.182	40075	30035	21450
TP FBed +R	4.674	1.722	1.206	37950	32850	22550
TP Fbed	4.292	1.491	1.029	36370	28950	19800
Average	7.143	2.593	1.984	48395	42125	29920

risk of floods or droughts in flood prone areas and improve livelihoods of small scale farmers in the Eastern Ganges.Carrot was also compared using two planting methods in on-farm trials (Table 3). Bed planting out yielded the traditional method of carrot planting, in which seed is surface broadcasted followed by ridge making with a ridger. Such a practice wastes expensive seed, thereby lowering plant density and yield. Maximum profitability was recorded with carrot grown on wide beds (Rs 56250 ha^{-1}), followed by *narrow beds* carrot technology (Rs 41250 ha^{-1}). Furthermore, the wheat-equivalent yield was much higher than the yield of wheat generally reported in the region (4-5tha^{-1}).Water productivity of bed planting was almost double the traditional system (Table 3).Improved planting techniques also showed potential for cabbage cultivation. Cabbage yield was higher when seeded with a precision planter or transplanted on 120 cm wide raised beds at the top as compared to traditional planting on sloppy ridges (Table 1). High value vegetable crops such as cabbage, carrot, okra can be established by direct dry seeding on the raised beds using a precision planter attached to a tractor fitted with narrow wheel tires. Net returns were almost half when using the farmer practice of cabbage cultivation on the ridges (Table2). Planting two rows on the top of the ridges (10-12 cm apart) increases inter-row competition resulting in significantly lower yield. Farmer participatory trials were also conducted using wider beds 120 cm on the top and with a 30 cm wide furrow used for irrigation.

Table 3 : Effect of tillage and crop establishment techniques on productivity and profitability of Cauliflower and Carrot.

Crop establishment	Yield t ha^{-1}		Net profit(Rs ha^{-1})	
	Cauliflower	Carrot	Cauliflower	Carrot
DS/TPNBed+R	21.5	23.5	44525	41250
DS/TPNBed	20.7	21.7	42100	34250
DS/TPWBed+R	24.7	29.6	59400	56250
DS/TPWBed	21.6	26.5	49120	49000
DS/TPFBed+R	18.9	20.6	36700	31500
DS/TPFBed	17.9	18.7	32500	26750
Average	20.77	23.43	37725	35825

DS/TPNBed+R- Direct seeded/transplanted on narrow beds with residue, DS/TPNBed- Direct seeded/transplanted on narrow beds,DS/TPWBed +R- Direct seeded/transplanted on wide beds with residue,DS/TPWBed-Direct seeded/transplantes on wide beds, DS/TPFBed +R- Direct seeded/transplanted on flat beds with residue, DS/TPFBed- Direct seeded/transplanted on flat beds.

Table 4: Productivity and profitability of Turmeric(T) and Okra (O) crop under permanent bed planting in farmer managed plots.

Crop establishment	Yield t ha^{-1}		Total water use (mm ha^{-1})		Water productivity (kg yield m^{-3} water)		Net profit (Rs ha^{-1})	
	T	O	T	O	T	O	T	O
DS/Nbed+R	21.5	8.5	440	485	4.886	1.753	115500	48250
DS/Nbed	19.8	7.3	460	495	4.304	1.475	103600	41500
DS/WBed+R	22.7	11.5	397	450	5.718	2.556	130900	67500
DS/Wbed	20.2	9.3	425	485	4.752	1.918	109200	49275
DS/FBed+R	16.5	6.5	485	570	3.402	1.140	87500	33560
DS/Fbed	15.8	5.8	515	590	3.068	0.983	81250	30500
Average	19.4	8.2	453.7	512.5	4.276	1.600	104650	46030

DS/TPNBed+R- Direct seeded/transplanted on narrow beds with residue, DS/TPNBed- Direct seeded/transplanted on narrow beds,DS/TPWBed +R- Direct seeded/transplanted on wide beds with residue, DS/TPWBed- Direct seeded/transplantes on wide beds, DS/TPFBed +R- Direct seeded/transplanted on flat beds with residue, DS/TPFBed- Direct seeded/transplanted on flat beds.

Complete Package – Intercropping:

Bed planting in an agronomic intervention where intercrop is sown on beds. The setts of sugarcane are placed end to end in the furrows. Immediately, the setts are covered with thin mass of soil (1 inch) through locally designed Pyramid shaped raker, then light irrigation is given in the furrows of furrow irrigated raised bed system (FIRBS). The intercrops of mustard emerge as usual within a week. Whereas the emergence of sugarcane commences 2-3 weeks after planting. Sugarcane crop remains dormant during winter months and offer no competition during the grand growth period ofmustard. Because of this nature any crop of vegetable which fits in the system can be taken up. The experience during last two years has shown that garlic and onion are the best intercrops in addition to mustard.This crop offers no competition during mustard maturity because of its slow growth behaviour upto mustard harvest.Sugarcane itself a widely spaced and very slow growing during winter period offers no competition to the mustard crop. Both crops grow in complementary manner. It is possible to get the potential yield of mustard crop with no significant effect on the cane yield. The salient features of the technology are :

1. The longevity of the sugarcane crop period by autumn planting translates into yield gains.

2. The early maturity of the cane in case of autumn planting is always welcomed by sugar industry ensuring longer crushing period.

3. The potential yield of mustardcrop is an incentive to the farmers in terms of better profitability.

4. The plant population in sugarcane is the most important determiner of cane yield. The proper moisture situation in FIRBS system ensures better and synchronous emergence of sugarcane.The yield is definitely high. Such gain can be further strengthened with two key interventions:

(a) Field should be laser levelled prior to the adoption of FIRBS. This makes water management easy by reducing the infiltration opportunity time, quick flow in the furrows with no chance of water stagnation.

(b) The farmer can use two-budded setts of sugarcane with much higher percentage of emergence. The two-budded setts have the advantage over three or more budded setts even in conventional practice. The gain is comparatively more in FIRBS system.

5. In FIRBS system here or in any crop situation saves water and ensures proper moisture regime to the crop. This is a kind of resource conservation technology permitted in one or the other system.

Synergy with Laser Leveling

Precision land levelling with laser leveller is the basic requirement for uniform crop stand.Unevenness in the soil surface adversely affects the uniform distribution of irrigation water in the fields and leads to poor crop stand. Laser levelling helps to overcome this inefficiency and reduces water requirement through transmission losses and uniformity in moisture distribution.Laser land levelling helps to:

- Save irrigation water.
- Increase cultivable area by 3 to 5 per cent.
- Improve crop establishment
- Improve uniformity of crop maturity.
- Increase water application efficiency upto 50 per cent.
- Increase cropping intensity by about 40 per cent.

- Increase crop yields.
- Facilitate management of saline environments.
- Reduce weed problems and improve weed control efficiency.

The use of laser leveller would further help farmers to make better use of furrow irrigated bed planting system based intercropping.

Sugarcane+Mustard

Sugarcane+Mustard is also a viable system .There is complementarity between two crops.

1. The most optimum time of sowing of both crops coincides i.e. 1st fortnight of October.
2. The sugarcane germination takes place within 3-4 weeks, whereas in winter sown crop buds remain dormant till February and germination start there after.
3. The mustard crop vacates the field by mid March, thus provides best time for interculture operations, nutrient management, etc. In sugarcane+mustard intercropping system, the target is often for a moderate yield of mustard with potential yield of sugarcane.The yield of 15-18 q ha^{-1} of mustard is achievable in this system with no effect on the sugarcane yield.

Sugarcane+Gram/Lentil

In this system, erect type varieties of gram should be preferred. Two lines of gram/lentil are sown on beds with the help of bed planter and sugarcane is sown in furrow in the I^{st} forth night of October. Light irrigations as per requirement of sugarcane crop are applied. This system produces 12-15 q ha^{-1} yield of gram/lentil. Since gram is not a preferred crop of rice-wheat cropping system, this option may not be accepted by the farmers on large scale.

Sugarcane+Garlic

As the spices (garlic/onion) are very remunerative and labour intensive, their intercropping in autumn sugarcane may increase the income level as well as employment potential for small farmers. Apart from this, these crops also possess peculiarodour which may serve as a repellent to the insect-pests of sugarcane.Verma *et al.* (1981) observed significant reduction in top borer incidence when spices were intercropped with sugarcane crop. In case of garlic+ sugarcane intercropping system, planting of sugarcane is done in the month of October and simultaneously cloves of garlic are manually planted on beds in rows and field is immediately irrigated. Garlic yield frosugarcane +garlic intercropping system ranges from 50- 62.5 q ha^{-1}.

Sugarcane+Onion

Four to five rows of onion are planted on beds depending upon the spacing. Sugarcane crop is planted in the end of September to first week of October alongwith the potato as intercrop. After uprooting the potato for vegetable purpose, the onion crop is transplanted between inter row spaces. Sugarcane+ onion intercropping may be done after taking sole crop of potato for vegetable purpose and after uprooting of potato, sugarcane+onion crops are intercropped in bed furrow system simultaneously. Onion crop produces yield of 175- 200 q ha^{-1} without any adverse effect on sugarcane yield. For control of weeds in vegetable crops, application of Stomp @ 2.5-3 l ha^{-1} is recommended.

Sugarcane+Potato

Intercropping of sugarcane+potato is also very profitable. In this system, sugarcane is planted at 90 cm distance in 1st week of October and one row of potato is planted between two rows of sugarcane .Sugarcane crop is irrigated as per needs of potato crop. Potato yields to the tune of 225 q ha^{-1} may be obtained

from intercropping system. Based on the existing agronomy, patato based intercropping is not easy and may not be practiced.

Sugarcane+Other Vegetables

In autumn planted sugarcane, vegetables like coriander, cauliflower, spinach, cucumber, okra,cabbage, etc.can also be grown successfully as intercrop depending upon the resources available with the farmer. Some more enterprising farmers first take potato as an intercrop. The potato is dug out in the month of January and then transplanting of onion or cucumber is done in inter row as intercrop. Such systems are area specific and there are enormous opportunities to integrate one or the other crop in FIRB system

Economics of Different Intercropping Systems:

Economics of different intercropping systems presented in Table 5 clearly showed the advantage of intercropping system over sole crop of sugarcane. Among different intercropping systems, sugarcane+garlic gave maximum net return to the tune of Rs.1,46,500 ha^{-1} followed by sugarcane+onion (Rs.1,18,500 ha^{-1}). The net returns

Sugarcane+potato+cucumber

Sugarcane+cauliflower

Sugarcane+coriander

Sugarcane+spinach

Fig. 2: Intercropping of vegetables in sugarcane

Table 5. Economics (Rs. ha^{-1}) of sugarcane based intercropping systems

Intercropping system	Yield (q ha-1)		Total expenditure	Gross returns	Net return
	Sugarcane	Intercrop			
Sugarcane+Garlic	875	60.5	109850	233500	146500
Sugarcane+Onion	875	175	87000	205500	118500
Sugarcane+Potato	825	200	89520	190420	100900
Sugarcane+Potato+Cucumber	850	200	101000	217000	116000
Sugarcane+Cauliflower	815	11.5	95000	179500	84500
Sugarcane sole	825	-	63000	125500	62500

obtained from sugarcane+vegetable crop depend on prevailing market prices. In the two years of the study, vegetable based intercropping systems were found more profitable, sugarcane + garlic being the highest followed by sugarcane+onion, sugarcane+potato+cucumber and sugarcane+cauliflower. The contribution of the vegetable component is responsible for certain edge over the sugarcanesole.

Despite the favourable economics, we can not undermine the fact that vegetables are perishable commodities and often exhibit wild price fluctuations.There has been years in the past where glut in the market caused market crash and the farmers running hard even to recover the cost of production. The case of garlic in the year 2000-01 is with us. Consistent with the general inflation in the economy during last three years, all horticultural crops showed price increase with reasonable degree of stability.

The sustainability of this price trend may be a problem in the future, when the government is also trying hard to control the inflation. So, this economic trend needs to be analyzed with caution and the jumping on conclusions may prove an illusion. In contrast wheat is our principal food crop enjoying the umbrella of support price. Keeping in view the global trends and food availability within the country wheat prices are most likely to increase in the coming years. Therefore, sugarcane+wheat may be good option.

Any piece of technology can generate tangible benefits if adopted at certain volume. Even marginal increase in widespread technology may contribute much more to the economy of the farmer and the country than a technology with handsome returns but restricted to few people.

There is a limit to horizontal expansion of vegetable based intercropping systems.Labour for agricultural purpose is a constraint in industrial hubs. The North West India is witnessing an industrial revolution. All agrarian work is dependent on migratory workforce from Bihar and adjoining states. The vegetable based intercropping systems are labour intensive. These are good options for employment generation in case we have surplus manpower. But the costly labour and restricted availability many a times creates logistic problems, timely operations are not done, means loss of production and profit margin. This issue has relevance in any plan of horizontal expansion of these crops.

One of the main channels through which diversification towards high-value crops can reduce poverty is via the participation of small farmers. However, although smallholders have the benefits of proportionally larger labor pools, this may be offset by constraints such as lack of access to credit. Thus, there is continued debate as to whether smallholders can successfully diversify into the high-value sector.

This is not to say, of course, that the observed level of diversification is necessarily the optimal level. Given the high labor endowments in India and the preponderance of smallholders, the share of resources allocated to high-value agriculture continues to be relatively small, although it is increasing over time. Conditional on supporting infrastructure and institutions, smallholders have an advantage when adopting labor-intensive crops such as vegetables. The bias towards vegetables rather than fruits clearly points to the role of enabling factors in transforming the potential advantages of the smallholders (such as larger families) into realized crop choices that favor high-value products.

The project has developed and promoted a number of ICRM modules with RCTs, which encompass practices that (1) enhance resource- or input-use efficiency; (2) provide immediate, identifiable, and demonstrable economic benefits such as reductions in production costs, and savings in water, fuel, and labor requirements; and (3) ensure timely crop establishment and uniform crop stands, resulting in higher crop yields. Indirect benefits include (1) effective weed management; (2) replacement of residue burning by retention of crop residues, resulting in some improvement in certain soil quality parameters, including short-time accumulation of carbon in surface soil;(3) buildup of soil fertility over the long term,leading to sustainability of intensive vegetables cultivation; and (4) the generation of rural employment by training and empowering local farm machine manufacturers, custom-hire service providers, retailers and traders, and seed producers. Although ICRM with tillage and crop establishment options has been more successful incabbage,the next frontier will be to make similar headway in carrot. In short, integrating new RCTs into the portfolio of farmers' current technologies using the framework of ICRM (good agronomy) will continue to be a key to improving productivity and production and eventually attaining national food security.

Farmer adoption of ICRM with new RCTs is highly variable in different regions of theNorth West India.This is due to differences in (1) farmers' knowledge, skills, resource endowments, and cultivation practices; (2) agro-climatic conditions and land types; (3) the time of introduction of ICRM with new RCTs; and (4) policy and institutional support to farmers. Other factors responsible for differential farmer adoption of ICRM include the shortage, high cost, and poor use of adapted farm machines and tools in villages and improper use of RCTs within ICRM.

The multistakeholder partnership adopted in the project was particularly successful in bringing together public- and private-sector innovators, investors, and implementers to develop and promote the system and region-specific ICRM and related technologies. Although, in general, the successes made so far are widely applauded (Seth et al 2003, Erenstein and Laxmi 2008, Hazell and Wood 2008, Raitzer and Kelley 2008), much greater effort is needed to fine-tune and mainstream the ICRM modules with these technologies as a regular feature of program planning and implementation by country scientists.What we need now is to develop an effective program for wider evaluation, refinement, and dissemination of ICRM with proven RCTs to deprived farming communities outside project areas to realize their great impact on food security and farmers' livelihood inNorth West India. For this to happen, we need to sensitize agricultural policymakers and encourage them to allocate more resources for wider dissemination of successful ICRM modules with new RCTs in the region. In addition, there are needs to (1) foster new models of public-private partnerships, especially for faster, scalable, and sustainable delivery of improved ICRM options along with associated knowledge; and (2) create a highly qualified professional workforce for private- and public-sector extension by establishing a program. Finally, improving the knowledge and skills of farm workers is critical for success in the field.

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STRUCTURAL CHANGES OVER TIME IN COST OF CULTIVATION OF MAJOR KHARIF CROPS IN RAJASTHAN

LATIKA SHARMA[1] AND K.A.VARGHESE[2]

[1]*Field Officer,* [2]*Officer Incharge, Centrally sponsored study on cost of cultivation of principal crops in Rajasthan, Rajasthan College of Agriculture, MPUAT,Udaipur*

ABSTRACT

In this paper, attempt has been made to assess the temporal changes in the economic parameters of major kharif crops like bajra, maize, soyabean, sesamum, moong and cotton of Rajasthan state which are characterized by high inter-regional heterogeneity and inter-year variations in the performance. The study is based on secondary data under centrally sponsored cost of cultivations studies in Rajasthan. The results indicated that for majority of crops, changes in cost of cultivation over time are more pronounced in operational cost items than in fixed cost items. Among the operational cost items, the increase in cost of human labour in crops like maize, soyabean and sesamum is totally attributable to increase in their wage rates as the physical use of human labour in these crops has declined over time while in bajra and cotton both increased physical use of human labour and hike in wage rates are responsible for this increase. For all the crops prices of seed have increased over time while the seed use has increased marginally or remained static over the years. Fertilizer in physical terms as well as it prices were found increased for all the crops. In bajra, moong and soyabean use of bullock labour hour has shown a declining trend while the prices of bullock labour have increased over time for all the crops. In moong the use of bullock labour has increased. The magnitude of disposable income which is measured as the residual of gross return over cost A_2 has gone up for all kharif crops over the years. The net profit over cost C_2 remained negative for maize, moong and sesamum in nineties. However during current decade only maize crop was found having negative profit. Thus the technological interventions made for the kharif crops proved to be cost effective for all crops except maize.

Key words: Operational cost, fixed costs, disposable income, gross and net returns.

India has made spectacular progress since independence in the field of agriculture in terms of growth in production and yield as well as area substitution by more profitable crops. Since late sixties, multi-pronged approaches of adoption of high-yielding varieties, increased nutrient application and expansion in irrigation facilities set in the process of technological transformation in Indian agriculture. The policy interventions and institutional support also resulted in the accelerated growth of Indian agriculture. However, the fruits of green revolution were not bestowed uniformly across crops and regions. The technological transformation has been more pronounced for few crops and in certain regions only. The cost of cultivation of crops has undergone not only upward swing but structural changes..

Structural changes in costs are due to changes in the quantity and quality of inputs associated with the technological process and also due to change in prices. The shift in relative shares of operational costs and fixed costs also has important implications for capital formation and income distribution in the agricultural sector. In Rajasthan gross cropped area is around 21 M ha. and the net sown area is 16.5 M ha. Out of net sown area more than two third is still under rainfed condition where only a single crop is being cultivated mostly in *kharif* season and the land remains fallow during the other seasons. Adequate knowledge of cost structure of major *kharif* crops has become essential for providing suitable incentives to the farmers and also to assess the relative competitiveness of *kharif* crops in a water scarce state like Rajasthan.

MATERIALS AND METHODS

The study is based on estimates of cost of cultivation of major *kharif* crops in Rajasthan for the years of early Nineties and also early years of the new millennium under centrally sponsored cost of cultivation studies in the state. Data for the study have been obtained from the reports of cost of cultivation of principal crops in India and also from the reports of the Commission for Agriculture Costs and Prices (CACP) and publications of Directorate of Economics and Statistics, Govt. of India, New Delhi.

The crops selected for the study are bajra, maize, soyabean, sesamum, moong and cotton which are the major cereal, oilseed, pulse and cash crops of Rajasthan grown in *kharif* season. Cost structure of each crop was analyzed by working out the share of each item of cost in the total cost of cultivation. The changes in the structure of cost of cultivation of crops were analyzed for two points of time. For bajra, maize and sesamum the cost structure of each crop was compared for 1992-93 with that of 2003-04, while for soyabean and cotton the cost structure of crops was compared for 1994-95 with that of 2003-04. For moong the estimates of 1999-2000 have been compared with that of 2003-04. Non-availability of regular published data has led to this difference in the reference period of study for different crops. The share of total temporal change as assignable to individual cost components has also been ascertained. The cost of production of the grain yield on per quintal basis has been worked out after the apportionment of total cost of cultivation between the main product and the by product in proportion to their contribution to the gross value of output. The apportionment of joint cost and other cost items have been made using the standard procedure being followed in the cost study scheme.

RESULTS AND DISCUSSION

Structural Changes in the Cost of Cultivation of Bajra

The changes over time in the cost of cultivation of bajra in Rajasthan are shown in Table 1.

The total cost of cultivation of bajra has gone up from Rs.2143 ha^{-1} in 1992-93 to Rs.6597 ha^{-1} in 2003-04 depicting three times increase during a period of twelve years. All the major items of cost like human labour, machine labour seed, fertilizer, manure, irrigation charges, rental value of owned land and interest on working capital as well as fixed capital have contributed positively towards the increase in the cost of cultivation over the period under study. But the cost due to bullock labour, and rent for leased in land has declined over time. Out of the total increase of Rs. 4454 in the cost of cultivation per hectare, the contribution of operational cost items was 70.60 per cent and that of fixed cost items was 29.40 per cent. Thus a major portion of the increase in the total cost of cultivation per hectare is because of operational cost items. Among the operational cost items, imputed value of family labour recorded the maximum share of 39.96 per cent in the increase in cost of cultivation overtime. The cost of machine labour has contributed 14.5 per cent of the

Table 1. Cost Structure and Changes in Cost of Cultivation of Bajra

Items	Cost of Cultivation				Change in 2003-04 Over 1992-93		Share in Total Change (%)
	1992-93		2003-04				
	Rs/ha	%	Rs/ha	%	percent	Rs./ha	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(a)Operational Cost							
Human labour Hired	135.06	6.30	476.19	7.22	341.13	252.58	7.66
Human labour Family	763.43	35.63	2543.24	38.55	1779.81	233.13	39.96
Bullock Labour	111.24	5.19	73.87	1.12	-37.37	-33.59	-0.84
Machine Labour	238.24	11.12	884.26	13.40	646.02	271.16	14.50
Seed	42.33	1.98	200.81	3.04	158.48	374.39	3.56
Manure	48.39	2.26	117.19	1.78	68.8	142.18	1.54
Fertilizers	13.14	0.61	143.78	2.18	130.64	994.22	2.93
Insecticides	-	-	0.26	0.00	0.26	-	0.01
Irrigation Charge	21.32	1.00	36.99	0.56	15.67	73.50	0.35
Interest on working capital	19.07	0.89	60.42	0.92	41.35	216.83	0.93
Total Operational Cost	1392.22	64.98	4537.01	68.77	3144.79	225.88	70.60
(b)Fixed Cost							
Land revenue cess & taxes	3.09	0.14	2.88	0.04	-0.21	-6.80	0.00
Depreciation on Imp. & Build.	61.82	2.89	166.43	2.52	104.61	169.22	2.35
Rent paid for lease in land	45.92	2.14	28.76	0.44	-17.16	-37.37	-0.39
Rental Value for owned land	421.56	19.67	1238.92	18.78	817.36	193.89	18.35
Int. on Fixed Capital	218.07	10.18	623.15	9.45	405.08	185.76	9.09
Total Fixed Cost	750.46	35.02	2060.14	31.23	1309.68	174.52	29.40
Total Cost (C2) (a+b)	2142.68	100.00	6597.15	100.00	4454.47	207.89	100.00

increase in the total cost of cultivation. The share of operational cost has remained around 68.77 per cent in 2003-04, which was lower than that in 1992-93. But within the operational cost, the share of family labour and machine labour increased remarkably. The share of machine labour in the total cost increased from 11.12 per cent in 1992-93 to 13.40 per cent in 2003-04.

The decrease in the share of bullock labour may be on account of its substitution by machine labour. The share of fertilizer in the total cost has also increased from 0.61 per cent in 1992-93 to 2.18 per cent in 2003-04, which in absolute terms is an increase from Rs.13.14 ha^{-1} in 1992-93 to 143.78 ha^{-1} in 2003-04. The upward swing in acreage under hybrid bajra as evidenced from the higher seed values would have caused for increased use of fertilizers in bajra crop in Rajasthan.

The extent of change in physical inputs and their prices along with changes in physical output and their prices and gross return for bajra over time is given in Table 2.

When the extent of change in physical input overtime for bajra is compared with the change in cost, it could be concluded that the increase in labour cost is due to both increase in man hours per hectare as well as their wage rates. The positive change in the cost of seed is attributable to marginal increase on physical seed rate and large increase in the prices of seed over time. The physical quantity of manure as well as its prices has increased over time. This has led to an increase in the cost

Table 2. Extent of Change in Physical Inputs, Input Prices, Output, Output Prices and Gross Return for Bajra Over Time

Particulars	1992-93	2003-04	% Change
(a) Quantity of Inputs			
Seed (kg/ha)	5.03	5.9	17.30
Fertilizer (kg/ha)	1.74	11.92	585.06
Manure (Qtl/ha)	3.55	3.99	12.39
Human labour((man hr/ha)	235.83	342.01	45.02
Animal Labour(pair hr/ha)	10.92	2.72	-75.09
(b) Price			
Seed (Rs/kg)	8.42	34.02	304.04
Fertilizer (Rs/kg)	7.56	12.06	59.52
Manure (Rs/ton)	136.3	293.7	1154.8
Human labour((Rs/man hr)	3.81	8.836	131.92
Animal Labour(Rs/pair hr)	10.19	27.14	166.34
(c) Output (Qt/ha)			
Main Product	5.57	12.11	117.41
By Product	10.25	22.28	117.37
(d) Market price of output(Rs/qtl)			
Price of main product	261.44	377.64	44.45
Price of by product	122.5	132.95	8.53
(e) Value of output(Rs/ha)			
Value of Main product	1456.22	4573.23	214.05
Value of by product	1255.63	2962.18	135.91
Gross Return	2711.85	7535.41	177.87
(f) Cost of production(Rs/ton)	2071.3	3283.3	585.0
(g) Minimum support price (Rs./ton)	1450	5050	2482.8

of manure in absolute terms between 1993-94 and 2003-04, although its share in the total cost has declined. The decline in the share of bullock labour cost is primarily due to decline in the use of animal labour hours although their prices have increased over time. The gross return from bajra has recorded an increase of 177.87 per cent during the period of twelve years. The increase in gross return from bajra is attributable to the increase in the main and by product of bajra as well as increase in their prices over the years. It is also important to note that increase in the physical quantity of main product and by product has been much higher as compared to the rate of increase in the prices of main product of bajra. The cost of production of bajra has increased from Rs. 207.13 per quintal in 1992-93 to Rs. 328.3 per quintal in 2003-04. While the cost of production has recorded an increase of 58.50 per cent only during the twelve years, the minimum support prices of bajra recorded a much higher increase of 248.28 per cent implying positive price policy for bajra in the state. The realization of higher productivity resulted in offsetting the cost of production to a great extent.

Structural Changes in Cost of Cultivation of Maize

The cost of cultivation of maize increased from Rs. 5623 ha^{-1} in 1992-93 to Rs. 13972 ha^{-1} in 2003-04 showing an increase of 148.48 per cent during a span of twelve years. The increase in total cost is attributed to cost items such as human labour (family labour), bullock labour, machine labour, manures, fertilizers, rental value of owned land and interest on fixed capital. Out of the total increase of Rs.8349 in the cost of cultivation of maize during the period, 76.12 per cent was contributed by the operational cost items and the remaining 23.88 per cent by fixed cost items. Amongst the items of operational cost family labour bullock labour and machine labour accounted for 30.34, 17.60 and 7.74 per cent respectively of the increase in total cost. The relative shares of different inputs in the change of cost of cultivation of maize in 1992-93 and 2003-04 revealed that the share of operational cost items in the total cost of cultivation was 73.68 per cent in 2003-04 which is higher than that of 70.06 per cent in 1992-93. But within the operational cost, although all the operational cost items have increased in absolute amounts the shares of hired human labour, family labour, seed, fertilizer and irrigation charges were found to decrease over the years. Only the bullock labour, machine labour and manure showed a rise in relative share within the operational cost.

The extent and change in physical inputs and their prices alongwith changes in physical output and their prices and gross return for maize overtime is given in Table 4.

The change in the cost of human labour for maize is totally attributable to increase in wage rates since the extent of use of human labour for maize cultivation has marginally declined over the years. The positive change in cost of cultivation due to seed for maize is also due to large increase in the prices of seed as the physical seed rate of maize is seen to be marginally decreased over the years. The practice of sowing hybrid maize in predominant maize growing areas where facilities for protective irrigation are available lead to such a rise in seed prices of maize. As far as fertilizer is concerned, the positive change in fertilizer cost is due to both increased use of physical quantity of

Table 3. Cost Structure and Changes in Cost of Cultivation of Maize

Items	Cost of Cultivation				Change in 2003-04 Over 1992-93		Share in Total Change (%)
	1992-93		2003-04				
	Rs/ha	%	Rs/ha	%	percent	Rs/ha	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(a)Operational Cost							
Human labour Hired	263.81	4.69	531.78	3.81	267.97	101.58	3.21
Human labour Family	1794.03	31.90	4326.8	30.97	2532.77	141.18	30.34
Bullock labour	940.95	16.73	2410.45	17.25	1469.5	156.17	17.60
Machine labour	80.06	1.42	726.48	5.20	646.42	807.42	7.74
Seed	141.68	2.52	325.23	2.33	183.55	129.55	2.20
Manure	141.94	2.52	711.87	5.09	569.93	401.53	6.83
Fertilizers	432.15	7.69	938.33	6.72	506.18	117.13	6.06
Insecticides	-	-	29.59	0.21	29.59	-	-
Irrigation Charge	79.8	1.42	113.32	0.81	33.52	42.01	0.40
Interest on working capital	65.01	1.16	180.85	1.29	115.84	178.19	1.39
Total Operational Cost	3939.43	70.06	10294.7	73.68	6355.27	161.32	76.12
(b)Fixed Cost							
Land revenue cesses & taxes	10.87	0.19	8.03	0.06	-2.84	-26.13	-0.03
Depreciation on Imp. & Build.	175.64	3.12	360.81	2.58	185.17	105.43	2.22
Rent paid for lease in land	159.38	2.83	379.07	2.71	219.69	137.84	2.63
Rental Value for owned land	680.97	12.11	1862.13	13.33	1181.16	173.45	14.15
Int. on Fixed Capital	656.89	11.68	1067.7	7.64	410.81	62.54	4.92
Total Fixed Cost	1683.75	29.94	3677.74	26.32	1993.99	118.43	23.88
Total Cost (C2) (a+b)	5623.18	100.00	13972.44	100.00	8349.26	148.48	100.00

fertilizer as well as increased prices of fertilizers. The rise in the cost of cultivation of maize due to manure is because of marginal increase in the use of physical quantity of manure alongwith a steep hike in the price of manure. Although the use of bullock labour has come down drastically over the years in maize cultivation, the cost due to bullock labour is still increasing because of rising bullock labour rates which has shown an increase of 291.02 per cent over the period of twelve years. The gross return from maize crop has recorded an increase of 155.48 per cent during the time span of twelve years. The increase in gross return from maize is attributable to the increase in the yield

Table 4. Extent of Change in Physical Inputs, Input Prices, Output, Output Prices and Gross Return for Maize over Time

Particulars	1992-93	2003-04	% Change
(a) Quantity of inputs			
Seed (kg/ha)	32.25	29.1	-9.77
Fertilizer (kg/ha)	59.26	76.17	28.54
Manure (t/ha)	104.9	164.9	572.0
Human labour((man hr/ha)	705.69	605.97	-14.13
Animal Labour(pair hr/ha)	115.77	75.82	-34.51
(b) Price of inputs			
Seed (Rs/ha)	4.39	11.18	154.67
Fertilizer (Rs/kg)	7.29	12.32	69.00
Manure (/Rs/Qtl)	13.63	43.2	216.95
Human labour((Rs/man hr)	2.92	8.02	174.66
Animal Labour(Rs/pair hr)	8.13	31.79	291.02
(c) Output (Qt/ha)			
Main Product	11.46	19.11	66.75
By Product	29.68	49.5	66.78
(d) Market price of output(Rs/qtl)			
Price of main product	294.3	473.11	60.76
Price of by product	44.59	59.32	33.03
(e) Value of output(Rs/ha)			
Value of Main product	3372.72	9041.05	168.06
Value of by product	1323.37	2936.54	121.90
Gross Return	4696.09	11977.59	155.05
(f) Cost of production(Rs/t)	3469.1	5555.6	601.5
(g) Minimum support price (Rs/t)	2450	5050	1061.2

of main and by product of maize as well as their prices over the years. The rate of increase in the physical output of main and by product of maize is higher as compared to increase in the prices of main and by product of maize. When the growth in prices of main product and by product is compared with the growth of prices of inputs, it is seen that the growth in prices of inputs is much higher than the growth in prices of output over the years. The cost of production of maize has increased from Rs. 346.91 per quintal in 1992-93 to Rs. 555.56 per quintal in 2003-04 which is a growth of 60.15 per cent over the period. Remarkably, the minimum support prices of maize for the same period recorded an increase of 106.12 per cent.

Structural Changes in the Cost of Cultivation of Soyabean

The results in Table 5 show the structural changes in the cost of cultivation of soyabean in Rajasthan.

Table 5. Cost Structure and Changes in Cost of Cultivation of Soyabean

Items	Cost of Cultivation				Change in 2003-04 Over 1994-95		Share in Total Change (%)
	1992-93		2003-04				
	Rs/ha	%	Rs/ha	%	percent	Rs./ha	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(a)Operational Cost							
Human labour Hired	250.42	3.89	1005.45	9.58	755.03	301.51	18.56
Human labour Family	1398.94	21.76	2052.98	19.56	654.04	46.75	16.07
Bullock Lobour	456.96	7.11	773.66	7.37	316.7	69.31	7.78
Machine Lobour	615.35	9.57	1201.45	11.44	586.1	95.25	14.40
Seed	861.97	13.41	1597.37	15.22	735.4	85.32	18.07
Manure							
Fertilizers	238.51	3.71	365.22	3.48	126.71	53.13	3.11
Insecticides	-	-	45.18	0.43	45.18		1.11
Irrigation Charge	92.13	1.43	-	-	-92.13	-100.00	-2.26
Intrest on working capital	78.6	1.22	155.89	1.48	77.29	98.33	1.90
Total Operational Cost	3992.88	62.10	7197.2	68.56	3204.32	80.25	78.75
(b)Fixed Cost							
Land revenue cesses & taxes	8.08	0.13	12.53	0.12	4.45	55.07	0.11
Depreciation on Imp. & F.Buld.	57.85	0.90	172.82	1.65	114.97	198.74	2.83
Rent paid for lease in land	221.61	3.45	87.02	0.83	-134.59	-60.73	-3.31
Rental Value for owned land	1653.8	25.72	2421.37	23.06	767.57	46.41	18.86
Int. on Fixed Capital(a+b)	495.11	7.70	607.15	5.78	112.04	22.63	2.75
Total Fixed Cost	2436.45	37.90	3300.89	31.44	864.44	35.48	21.25
Total Cost (C2) (a+b)	6429.33	100.00	10498.09	100.00	4068.76	63.28	100.00

In Rajasthan yellow soyabean is grown predominantly in south-eastern belt. The total cost of cultivation per hectare of soyabean increased from Rs 6429 in 1992-93 to Rs 10498 in 2003-04, showing an increase of 63.28 per cent over the time span of 10 years. The increase in cost of cultivation has occurred in all major items of cost such as human labour, bullock labour, machine labour, seed, fertilizers rental value of own land and interest on fixed capital. Out of total increase of Rs.4069 in the cost of cultivation per hectare of soyabean over the years, 78.75 per cent was attributable to operational cost and 21.25 per cent to fixed cost items. The major items of operational cost which caused for the increase in cost of cultivation were hired human labour (18.56%), family labour (16.07%), seed (18.07%) and machine labour (14.40%). Out of total fixed cost items, rental value for owned land has contributed 18.86 per cent share of the increase in fixed cost. The relative shares of different inputs in the cost of cultivation of soyabean at two points of time revealed that the share of operational cost has risen from 62.10 per cent in 1994-95 to 68.56 per cent in 2003-04. Within the operational cost, the shares of family labour, fertilizers and irrigation charges had declined marginally. The operational cost items for which the relative shares had increased include hired human labour, machine labour, seed and insecticides.

The extent of change in physical inputs and their prices alongwith changes in physical output and their prices and gross return for soyabean over time is given in Table 6.

The positive change in the cost of seed is attributable to both higher seed rate in physical terms as well as increase in the price of seed. The same situation holds true for cost of fertilizer where

Table 6. Extent of Change in Physical Inputs, Input Prices, Output, Output Prices and Gross Return for Soyabean Over Time

Particulars	1992-93	2003-04	% Change
a) Quantity of inputs			
Seed (kg/ha)	82.6	93.57	13.28
Fertilizer (kg/ha)	22.3	27.69	24.17
Manure (Qtl/ha)	-	-	-
Human labour((man hr/ha)	339.07	398.88	17.64
Animal Labour(pair hr/ha)	31.71	25.02	-21.10
(b) Price of inputs			
Seed (Rs/ha)	10.44	17.07	63.51
Fertilizer (Rs/kg)	10.7	13.19	23.27
Manure (/Rs/Qtl)	-	-	-
Human labour((Rs/man hr)	4.86	7.67	57.82
Animal Labour(Rs/pair hr)	14.41	30.93	114.64
(c) Output (Qt/ha)			
Main Product	11.72	10.74	-8.36
By Product	18.4	16.86	-8.37
(d) Market price of output(Rs/qtl)			
Price of main product	806.24	1307.47	62.17
Price of by product	47.9	49.38	3.09
(e) Value of output(Rs/ha)			
Value of Main product	9449.13	14042.27	48.61
Value of by product	881.36	832.59	-5.53
Gross Return	10330.49	14874.86	43.99
(f) Cost of production(Rs/qtl)	497.4	921.64	85.29
(g) Minimum support price(Rs/qtl)	650	930	43.08

both the physical uses of fertilizer as well as its price have increased over time in soyabean. It is remarkable to note that the use of human labour and animal labour per hectare has come down for soyabean crop over the years. Therefore, the positive change in the cost of both these items could be exclusively attributable to increase in wage rates and animal labour rates. The gross return from soyabean crop has recorded an increase of 43.99 per cent during the period of 10 years, which is attributable to the increase in the prices of main product and by product as the yield has marginally declined. The cost of production of soyabean has increased from Rs.497.40 per quintal in 1994-95 to Rs.921.64 in 2003.04. While the cost of production of soyabean has recorded an increase of 85.29 per cent per annum during 10 years, the minimum support prices recorded an increase of 47.37/ 43.08 per cent which is obviously less than the increase in the cost of production of soyabean indicating that the price policy of soyabean is not conducive for enhanced production of soyabean.

Structural Changes in the Cost of Cultivation of Sesamum

The result is Table 7 indicates the structural changes in the cost of cultivation of Sesamum in Rajasthan.

The per hectare cost of cultivation of sesamum increased from Rs.3081 in 1992-93 to Rs.6902 in 2003-04 indicating an increase of 2.2 times during a period of twelve years. The increase in cost has occurred in major inputs like family labour, bullock labour , machine labour , seed, fertilizer, interest on working as well as fixed capital and rental value of owned land. Cost due to hired human labour, manure, irrigation charge etc, has shown a declining trend. Out of the total increase of Rs.3820.77 in the total cost of cultivation per hectare of sesamum crop, 53.18 per cent was attributable to the operational cost and the remaining 46.82 per cent to the fixed cost. Out of the items of operational cost, the contribution of family labour was 37.07 per cent, machine labour 9.53 per cent and bullock labour was 6.12 per cent. Out of the fixed cost items, the rental value of owned land accounted for 34.31 per cent and interest on fixed capital accounted for 11.01 per cent of the total increase in the cost of cultivation. The share of operational cost in total cost of cultivation is 61.77 per cent in 2003-04 which is less than that in 1992-93. Thus, over the years the share of operational cost items have declined while the share of fixed cost items have increased from 27.57 per cent to 38.23 per cent in the cost of cultivation of sesamum. Within the operational cost the share of hired human labour decreased from 6.83 per cent to 2.81 per cent, family labour from 45.44 per cent to 40.80 per cent, seed from 4.23 per cent to 2.19 per cent and manure from 1.44 per cent to 0.30 per cent. The share of bullock labour, machine labour and fertilizers has increased marginally.

The extent of change in physical inputs and their prices along with changes in physical output and their prices and gross return for sesamum overtime is given in Table 8.

The positive increase in the cost of seed of sesamum is mainly because of rising prices of seed and not because of increase in physical input use as the physical quantity of seed being used for sesamum cultivation has declined from 6.09 kg/ha in 1992-93 to 4.67kg/ ha in 2003-04. As far as large increase in fertilizer cost is concerned, it is both

Table 7. Cost Structure and Changes in Cost of Cultivation of Sesamum

Items	Cost of Cultivation				Change in 2003-04 Over 1994-95		Share in Total Change (%)
	1992-93		2003-04				
	Rs/ha	%	Rs/ha	%	percent	Rs./ha	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(a)Operational Cost							
Human labour Hired	210.34	6.83	194	2.81	-16.34	-7.77	-0.43
Human labour Family	1400.04	45.44	2816.36	40.80	1416.32	101.16	37.07
Bullock Labour	138.8	4.50	372.79	5.40	233.99	168.58	6.12
Machine Labour	258.05	8.37	622.3	9.02	364.25	141.15	9.53
Seed	130.36	4.23	150.94	2.19	20.58	15.79	0.54
Manure	44.44	1.44	20.65	0.30	-23.79	-53.53	-0.62
Fertilizers	10.09	0.33	39.36	0.57	29.27	290.09	0.77
Insecticides	1	0.03	3.03	0.04	2.03	203.00	0.05
Irrigation Charge	13.35	0.43	0.23	0.00	-13.12	-98.28	-0.34
Interest on working capital	25.2	0.82	43.85	0.64	18.65	74.01	0.49
Total Operational Cost	2231.67	72.43	4263.51	61.77	2031.84	91.05	53.18
(b)Fixed Cost							
Land revenue cesses & taxes	3.76	0.12	3.22	0.05	-0.54	-14.36	-0.01
Depreciation on Imp. & Build.	101.38	3.29	184.18	2.67	82.8	81.67	2.17
Rent paid for lease in land	45.76	1.49	20.76	0.30	-25	-54.63	-0.65
Rental Value for owned land	442.5	14.36	1753.38	25.40	1310.88	296.24	34.31
Int. on Fixed Capital	256.23	8.32	677.02	9.81	420.79	164.22	11.01
Total Fixed Cost	849.63	27.57	2638.56	38.23	1788.93	210.55	46.82
Total Cost (C2) (a+b)	3081.3	100.00	6902.07	100.00	3820.77	124.00	100.00

because of enhanced use of fertilizers in physical terms as well as its rising prices. But the change is more pronounced in physical application of fertilizers per hectare. The cost due to hired human labour has declined over time while the cost of family labour has increased. This indicates that more and more hired labour is being replaced by the family labour in sesamum cultivation. When the physical use and prices of human labour are considered, even the positive change in family labour cost is mainly due to the increase in wage rate over time as the physical quantity of human labour for sesamum cultivation has declined marginally between 1992-93 and 2003-04. The gross

Table 8. Extent of Change in Physical Inputs, Input Prices, Output, Output Prices and Gross Return for Sesamum Over Time

Particulars	1992-93	2003-04	% Change
(a) Quantity of inputs			
Seed (kg/ha)	6.09	4.67	-23.32
Fertilizer (kg/ha)	1.35	2.82	108.89
Manure (Qtl/ha)	2.66	0.41	-84.59
Human labour((man hr/ha)	396.68	353.69	-10.84
Animal Labour(pair hr/ha)	15.63	12.9	-17.47
(b) Price of inputs			
Seed (Rs/ha)	21.39	32.32	51.10
Fertilizer (Rs/kg)	7.5	13.98	86.40
Manure (/Rs/Qtl)	16.71	50.04	199.46
Human labour((Rs/main hr)	4.06	8.51	109.61
Animal Labour(Rs/pair hr)	8.88	28.89	225.34
(c) Output (Qtls/ha)			
Main Product	2.5	3.66	46.40
By Product	1.71	11.66	581.68
(d) Market price of output(Rs/qtl)			
Price of main product	1116.06	2837.98	154.29
Price of by product	10	15	50.00
(e) Value of output(Rs/ha)			
Value of Main product	2790.15	10387.28	272.28
Value of by product	17.13	174.85	920.72
Gross Return	2807.28	10562.13	276.24
(f) Cost of production(Rs/qtl)	1224.12	1843.59	50.61
(g) Minimum support price (Rs/qtl)	NA	1485	-

return from sesamum crop has recorded an increase of 276.24 per cent during the period of twelve years which is attributable to the increase in prices as well as increase in physical yield of sesamum. The cost of production of sesamum has increased from Rs.1224.12 per quintal in 1992-93 to Rs.1843.59 per quintal in 2003-04

Structural Changes in the Cost of Cultivation of Cotton.

The results in Table 9 indicate the structural changes in the cost of cultivation of cotton.

The per hectare cost of cultivation of cotton increased from Rs.9831 in 1994-95 to Rs.17409 in 2003-04, a change of Rs.7578 over the period of 10 years. Operational cost accounted for 66.73 per cent increase in total cost while 33.27 per cent was contributed by fixed costs. The increase in cost has occurred in major inputs like human labour, machine labour, seed, fertilizer, irrigation charges and rental value for owned land. A fall in the cost of bullock labour and manure was also noted. Out of items of operational cost which caused for the increase in cost of cultivation of

Table 9. Cost Structure and Changes in Cost of Cultivation of Cotton

Items	Cost of Cultivation				Change in 2003-04 Over 1994-95		Share in Total Change (%)
	1994-95		2003-04				
	Rs/ha	%	Rs/ha	%	percent	Rs./ha	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(a)Operational Cost							
Human labour Hired	439.64	4463.19	1206	6.93	766.36	174.32	10.11
Human labour Family	2300.52	23.40	4463.19	25.64	2162.67	94.01	28.54
Bullock Labour	577.68	5.88	525.96	3.02	-51.72	-8.95	-0.68
Machine Labour	267.25	2.72	619.29	3.56	352.04	131.73	4.65
Seed	271.21	2.76	477.66	2.74	206.45	76.12	2.72
Manure	272.94	2.78	222.32	1.28	-50.62	-18.55	-0.67
Fertilizers	461.54	4.69	1551.21	8.91	1089.67	236.09	14.38
Insecticides	876.68	8.92	865.78	4.97	-10.9	-1.24	-0.14
Irrigation Charge	206.16	2.10	711.13	4.08	504.97	244.94	6.66
Interest on working capital	105.41	1.07	193.13	1.11	87.72	83.22	1.16
Total Operational Cost	5779.03	58.78	10835.67	62.24	5056.64	87.50	66.73
(b)Fixed Cost							
Land revenue cesses & taxes	8.9	0.09	7.83	0.04	-1.07	-12.02	-0.01
Depreciation on Imp. & Build.	172.59	1.76	351.67	2.02	179.08	103.76	2.36
Rent paid for lease in land	165.61	1.68	-	-	-165.61	-100.00	-2.19
Rental Value for owned land	2888.68	29.38	4233.41	24.32	1344.73	46.55	17.75
Int. on Fixed Capital	816.62	8.31	1980.82	11.38	1164.2	142.56	15.36
Total Fixed Cost	4052.4	41.22	6573.73	37.76	2521.33	62.22	33.27
Total Cost (C2) (a+b)	9831.43	100.00	17409.4	100.00	7577.97	77.08	100.00

cotton, the contribution of family labour was 28.54 per cent, fertilizers 14.38 per cent, hired human labour 10.11 per cent, irrigation chages 6.66 per cent , machine labour 4.65 per cent and seed 2.72 per cent. Out of fixed cost items, the rental value of owned land accounted for 17.75 per cent and interest on fixed capital accounted for 15.36 per cent of the total increase in the cost of cultivation. The relative shares of different inputs in cost of cultivation of cotton in 1994-95 revealed that the share of family labour was 23.40 per cent in 1994-95 which increased to 25.64 per cent in 2003-04. For the same period, the share of bullock labour has come down from 5.88 to 3.02 per cent while the share of machine labour has increased from 2.72 to 3.56 per cent. The share of cost due to manure has gone down from 2.78 per cent in 1994-95 to 1.28 per cent in 2003-04 while the share of cost due to fertilizers has increased from 4.69 per cent to 8.91 per cent.

The extent of change in physical inputs and their prices along with changes in physical output and their prices and gross return for cotton over time is given in Table 10.

The positive increase in the cost of seed of cotton over the years is mainly due to increase in prices of seed alongwith marginal increase in the physical quantity of seed being used for cotton cultivation. As far as large increase in fertilizer cost is concerned, it was mainly due to enhanced use of fertilizer in physical terms for cotton cultivation. The increase in prices of fertilizer also caused for the increase in the cost of cultivation of cotton. The positive change in human labour is mainly due to the increase in wage rate overtime. On the contrary, the decline in the cost of bullock labour over time is due to reduced use of animal labour for

Table 10. Extent of Change in Physical Inputs, Input Prices, Output, Output Prices and Gross Return for Cotton Over Time

Particulars	1992-93	2003-04	% Change
(a) Quantity of inputs			
Seed (kg/ha)	14.79	16.92	14.40
Fertilizer (kg/ha)	52.31	130.86	150.16
Manure (Qtl/ha)	13.82	5.64	-59.19
Human labour((man hr/ha)	529.69	615.63	16.22
Animal Labour(pair hr/ha)	40.45	17.05	-57.85
(b) Price of inputs			
Seed (Rs/ha)	18.33	28.24	54.06
Fertilizer (Rs/kg)	8.82	11.85	34.35
Manure (/Rs/Qtl)	19.75	39.43	99.65
Human labour((Rs/man hr)	5.17	9.21	78.14
Animal Labour(Rs/pair hr)	14.28	30.84	115.97
(c) Output (Qtls/ha)			
Main Product	11.08	10.19	-8.03
By Product	9.67	8.89	-8.07
(d) Market price of output(Rs/qtl)			
Price of main product	1589.53	2446.03	53.88
Price of by product	10	18	80.00
(e) Value of output(Rs/ha)			
Value of Main product	17611.96	24925	41.52
Value of by product	96.69	470.4	386.50
Gross Return	17708.65	25085.02	41.65
(f) Cost of production(Rs/qtl)	886.65	1674.02	88.80
(g) Minimum support price (Rs/qtl)	1000	1725	72.50

cotton cultivation as machine labour substituted the animal labour remarkably for many of the operations. The gross return from cotton has recorded an increase of 41.65 per cent during the period of 10 years which is attributable to increase in prices of main product as the physical yield of cotton has marginally declined from 11.08 quintals per hectare in 1994-95 to 10.19 quintals per hectare in 2003-04. The cost of production of cotton has increased from Rs. 886.65 per quintal in 1994-95 to Rs.1674.02 per quintal in 2003-04. The rate of increase in cost of production has been more than that for the support prices of cotton in the state indicating that the price policy is not conducive to increase production of cotton in the state.

Structural Changes in Cost of Cultivation of Moong

Moong is one of the major Kharif pulses in Rajasthan. The results in Table 11 indicate the structural changes in the cost of cultivation of moong at two points of time,ie 1999-2000 and 2003-04.

The study of the structural changes in the cost of cultivation of moong was carried out for the year 1999-2000 and 2003-04. It was found that the cost of cultivation of moong increased from Rs. 5113 ha^{-1} in 1999-2000 to Rs. 5972 ha^{-1} in 2003-04 showing an increase of 16.8 per cent over five years. Cost items such as bullock labour, fertilizer, insecticides, irrigation charges and rental value for owned land have shown increased overtime. Cost of seed, manure, machine labour and interest on fixed as well as working capital also increased to some extent. Out of the total increase of Rs. 858.88 in the cost of cultivation of moong per hectare, 41.86 per cent was contributed by the operational cost items and 58.14 per cent by fixed cost items. Amongst the items of operational cost, machine labour, seed and insecticides accounted for 14.30 per cent, 12.08 per cent and 10.41 per cent respectively, of the increase in total cost. Amongst the fixed cost items, rental value for owned land contributed 49.59 per cent to the increase in total cost.

The relative shares of different inputs in the changes of cost of cultivation of moong revealed that the share of operational cost items in the total cost of cultivation was 75.48 per cent in 1999-2000 which came down to 70.64 per cent in 2003-04, and the share of fixed cost items has increased from 24.52 per cent to 29.36 per cent during five years time. During this period the maximum increase was seen in rental value of owned land which has increased from Rs.666.83 per hectare in 1999- 2000 to Rs.1092.78 in 2003-04. This may be because of the recent surge in land prices in the state. Within the operational cost items, the share of hired as well as family labour declined, whereas the share of machine labour was found increasing. The extent and change in physical inputs and their prices along with changes in physical output, their prices and gross return for moong overtime is given in Table 12.

The increase in cost of cultivation of moong due to seed is attributable to both increased physical use of seed per hectare as well as its prices. The increase in the physical use of fertilizer is more pronounced than increase in fertilizer prices while in case of manure the increase in physical use of manure is only nominal and rise in its prices is more substantial. Although the use of animal labour has increased overtime, the increase in their prices were comparatively more significant. The gross return from moong has recorded

Table 11. Cost Structure and Changes in Cost of Cultivation of Moong

Items	Cost of Cultivation				Change in 2003-04 Over 1999-2000		Share in Total Change (%)
	1999-2000		2003-04				
	Rs/ha	%	Rs/ha	%	percent	Rs./ha	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(a)Operational Cost							
Human labour Hired	767.27	15.01	696.26	11.66	-71.01	-9.25	-8.27
Human labour Family	1780.36	34.82	1747.91	29.27	-32.45	-1.82	-3.78
Bullock Lobour	57.09	1.12	135.2	2.26	78.11	136.82	9.09
Machine Lobour	693.11	13.56	815.94	13.66	122.83	17.72	14.30
Seed	437.01	8.55	540.79	9.06	103.78	23.75	12.08
Manure	15.93	0.31	19.97	0.33	4.04	25.36	0.47
Fertilizers	25.36	0.50	70.38	1.18	45.02	177.52	5.24
Insecticides	13.47	0.26	102.87	1.72	89.4	663.70	10.41
Irrigation Charge	6.5	0.13	14.41	0.24	7.91	121.69	0.92
Interest on working capital	62.99	1.23	74.87	1.25	11.88	18.86	1.38
Total Operational Cost	3859.09	75.48	4218.6	70.64	359.51	9.32	41.86
(b)Fixed Cost							
Land revenue cesses & taxes	5.88	0.12	2.45	0.04	-3.43	-58.33	-0.40
Depreciation on Imp.& Build.	166.38	3.25	122.78	2.06	-43.6	-26.21	-5.08
Rent paid for lease in land	62.09	1.21	0.26*	0.00	-61.83	-99.58	-7.20
Rental Value for owned land	666.83	13.04	1092.78	18.30	425.95	63.88	49.59
Int. on Fixed Capital	352.72	6.90	535	8.96	182.28	51.68	21.22
Total Fixed Cost	1253.9	24.52	1753.27	29.36	499.37	39.83	58.14
Total Cost (C2) (a+b)	5112.99	100.00	5971.87	100.00	858.88	16.80	100.00

an increase from Rs 4155.75 per hectare in 1999-2000 to Rs 6555.2 per hectare in 2003-04. The increase in gross return in attributable to increase in the yield of main product as well as by product. The cost of production of moong has decreased from Rs 2207.40 per quintal in 1999-2000 to Rs 1335.81 per quintal in 2003-04, a decrease of 39.48 per cent, while the minimum support prices for moong has increased by 23.98 per cent for the same period of time. The inter-year performance of moong is more responsive to the extent and distribution of rains.

Table 12. Extent of change in Physical Inputs, Input Prices, Output, Output Prices, and Grows return for Moong Over Time.

Particulars	1999-2000	2003-04	% Change
(a) Quantity of inputs			
Seed (kg/ha)	16.02	17.85	11.42
Fertilizer (kg/ha)	1.86	4.59	146.77
Manure (Qtl/ha)	0.53	0.54	1.89
Human labour((man hr/ha)	312.78	306.52	-2.00
Animal Labour(pair hr/ha)	3.42	4.26	24.56
(b) Price of inputs			
Seed (Rs/ha)	27.27	30.29	11.07
Fertilizer (Rs/kg)	13.65	15.33	12.31
Manure (/Rs/Qtl)	30	36.97	23.23
Human labour((Rs/man hr)	8.15	7.97	-2.21
Animal Labour(Rs/pair hr)	16.7	31.75	90.12
(c) Output (Qtls/ha)			
Main Product	1.8	4.09	127.22
By Product	2.83	6.42	126.86
(d) Market price of output(Rs/qtl)			
Price of main product	1788.89	1468.67	-17.90
Price of by product	330.65	85.57	-74.12
(e) Value of output(Rs/ha)			
Value of Main product	3220.01	6006.85	86.55
Value of by product	935.74	549.35	-41.29
Gross Return	4155.75	6556.20	57.76
(f) Cost of production(Rs/qtl)	2207.4	1335.81	-39.48
(g) Minimum support price (Rs/qtl)	1105	1370	23.98

Comparative Economics Advantage of Major *Kharif* Crops

The cost and return of major *kharif* crops at two points of study are given in Table 13.

During early nineties net profit over cost A_2 and cost C_2 was highest for cotton followed by soyabean. Both cotton and soyabean are important cash crops of Rajasthan. Maize, moong and sesamum crops were profitable over cost A_2 but were unprofitable over cost C_2. Thus Maize, moong and Soyabean are profitable when only paid out costs are considered and they become unprofitable when imputed costs are also considered alongwith paid out costs. Bajra which is a staple food crop of Rajasthan is profitable both on cost A_2 and Cost C_2. Maize was unprofitable over cost C_2 during 2003-04 too. Therefore cotton has comparative economic advantage as compared to other major kharif crops of the state during early nineties as well as during 2003-04. However cotton is generally grown under ensured irrigation in the state.

Table 13. Cost and Return of Major *Kharif* Crops in Rajasthan

Particulars (1)	Bajra (2)	Maize (3)	Moong (4)	Soyabean (5)	Sesamum (6)	Cotton (7)
(A) Estimated Values for early nineties						
Cost A2	740	2491	2313	2881	983	3826
Cost C2	2413	5623	5113	6429	3081	9831
Gross Value	2712	4696	4156	10330	2807	17709
Profit Over Cost A2	1972	2205	1843	7449	1824	13883
Profit Over Cost C2	569	-927	-957	3901	-274	7878
(B) Estimated Values for 2003-04						
Cost A2	2192	6716	2596	5417	1655	6733
Cost C2	6597	13972	5972	10498	6902	17409
Gross Value	7535	11978	6556	14875	10562	25085
Profit Over Cost A2	5343	5262	3960	9458	8907	18352
Profit Over Cost C2	938	1994	584	4377	3660	7676

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RESOURCE CHARACTERIZATION OF MAJOR CROPPING SEQUENCES OF SUB-HUMID SOUTHERN PLAIN AND ARAVALI HILLS ZONE OF RAJASTHAN

HARI SINGH[1], N.K. JAIN[2] AND P.S. RAO[3]

AICRP on Cropping Systems (ECF), Rajasthan College of Agriculture,
Maharana Pratap University of Agriculture and Technology, Udaipur-313 001 Rajasthan.

ABSTRACT

Resource characterization survey on cropping sequences was carried out in Udaipur district of Rajasthan (Zone IVa, Sub-humid Southern Plain and Aravali Hills) during 2005-06 to study the cropping sequences, disposal pattern, income and employment pattern in the sample area. Maize – wheat is the dominant cropping system which occupied 86.45 per cent of the total irrigated cropped area. Maize- mustard and clusterbean –wheat occupied only 11.14 and 2.31 per cent of total irrigated cropped area, respectively. Total working cost of maize-wheat cropping system incurred by small, medium and large categories of farmers were Rs 17915, 19108 and 20104 ha^{-1}, respectively. It means as the size of land holding increases, farmers also increase the expenditure on crops due to more risk bearing capacity. About 66 to 75% of total grain produced was sold in the market to meet out the family expenditure by all categories of farmers. The large farmers sold about 20% of total fodder produced in the market due to surplus fodder available with them. The yield losses due to lack of irrigation facilities were estimated up to 19.2 per cent in maize, 20.2 per cent in wheat, 17.5 per cent in mustard and 14.6 per cent in groundnut. Non-availability of newly developed high yielding variety seeds (9.6-18.2 %) and imbalanced use of fertilizers (3.4-18.1 %) were also major constraints considerably influencing yield of all major crops grown in Udaipur.

Key words:

Rajasthan is the largest state of India with a geographical area of 342.65 lakh hectares and occupies 10.41 per cent land area of the country. The area on eastern and southern parts of the Aravalli hills has more diversified cropping pattern. In spite of unfriendly climate and other constraints, a wide variety of crops are being cultivated ranging from pearl millet to transplanted rice. Due to great diversity in soil and climatic conditions of the geographical area, about 46.30 per cent is under cultivation. Identification of efficient cropping systems with reference to productivity and sustainability has become imperative for different farming situations (Nanda *et al*, 1999). The whole state therefore, has been sub-divided in 10 agro-climatic zones to cater the need based and location specific research demand. The Sub-humid Southern Plain and Aravali Hills Zone (IVa) covering Bhilwara, Udaipur, Rajsamand, Chittorgarh and Sirohi district, where maize, wheat, gram, paddy and urd are the major crops. An alternative farming system, which yields not only higher income but also utilizes family labour efficiently, needs to be evolved. Further, the system should help in restoration of ecological balance. The study was conducted to examine the resource characterization, cropping sequences, disposal pattern and income and employment pattern in the study area.

[1]Assistant Professor, [2]Associate Professor, [3]Senior Technical Assistant.

MATERIALS AND METHODS

A survey was conducted out during 2005-06 in Udaipur district of Rajasthan (Zone IVa, Sub-humid Southern Plain and Aravali Hills). Using the stratified random sampling technique (Tehsil, village and farmers) and following the probability proportion sample size, 600 farmers belonging to size groups, based on the size of operational holding wise small (1-2 ha.), medium (2-4 ha) and large (above 4 ha.) were selected from six tehsils of Udaipur district. The data on socio-economic parameters, existing cropping system, resource use pattern, disposal pattern and employment pattern were obtained in pre-tested schedule. The survey was conducted by way of the questionnaires. The secondary data have been taken from published records of state and central government departments. Data were interpreted as averages and percentages.

RESULTS AND DISCUSSION

Size of land holding

Table1 indicated the average size of land holding occupied by different categories of farmers in study areas of Udaipur district of Rajasthan. Large category of farmers have average size of land holding of 5.78 ha whereas medium and small categories of farmers have only 2.95 and 1.32 ha average size of land holdings, respectively. This means that about 57.5 per cent of total land holdings was occupied by the large category of farmers while small farmers occupied only 13.1 per cent land holdings. Data also showed that small, medium and large categories of farmers were having 75.8, 64.1 and 56.6 per cent, respectively in irrigated area. This clearly showed the possibility of growing more than one crop in a year due to availability of irrigation water.

Cropping system

In Udaipur district, maize – wheat was the dominant cropping system which occupied 86.45 per cent of the total irrigated cropped area. Maize-mustard and clusterbean–wheat occupied only 11.14 and 2.31 per cent of total irrigated cropped area, respectively (Table 2).

Resource Use Patterns in major cropping systems

a. Maize –wheat cropping system

Total working costs of maize-wheat cropping system incurred by small, medium and large categories of farmers are Rs 17,915, 19,108 and 20,104 ha^{-1}, respectively (Table 3). It means that as the size of land holding increases, farmers also increase the expenditure on crops due to more risk bearing capacity. Small category of farmers expend about 8.0 per cent on ploughing, 4.5 per cent on planking, 13.8 per cent

Table1. Land holding distribution of farmers.

S.No.	Category and	Average area of holding (ha)			
	Size of farm	No. of farmers	Irrigated	Unirrigated	Total
1.	Small (1-2 ha)	478	1.00 (75.8)	0.32 (24.2)	1.32 (13.1)
2.	Medium (2-4 ha)	92	1.89 (64.1)	1.06 (35.9)	2.95 (29.4)
3.	Large(> 4 ha)	30	3.27 (56.6)	2.51 (43.4)	5.78 (57.5)

Figures in parentheses indicate per cent value

Table 2. Per cent area under different cropping systems.

S. No.	Cropping systems	Per cent area
1.	Maize-wheat	86.45
2.	Maize-mustard	11.14
3.	Cluster bean – wheat	2.31
4.	Others	0.10

on sowing, 9.0 per cent on seed, 7.8 per cent on manure, 7.8 per cent on fertilizers,12.3 per cent on irrigation, 9.9 per cent on weeds and insect pest control and remaining 26.9 per cent on harvesting and threshing of the total working cost. It showed that a significant amount was spending on ploughing, planking and sowing of crops by small categories of farmers. The money spent on purchase of newly developed high yielding variety seeds and fertilizers was quite unreasonable and indicate poor adoption of quality seed and recommended doses of fertilizers. Large farmers spend a sizeable portion of working cost on the purchase of quality seed material and thereby obtain higher yields in comparison to other categories of farmers.

Table 3. Resource use patterns in maize-wheat cropping system adopted by different categories of farmers (Rs /ha).

S.	Operations/	Small			Medium			Large		
No.	inputs	Maize	Wheat	Total	Maize	Wheat	Total	Maize	Wheat	Total
1.	Ploughing	716	716	1432 (8.0)	725	998	1723 (9.0)	700	700	1400 (7.0)
2.	Planking	350	450	800 (4.5)	256	294	550 (2.1)	300	300	600 (3.0)
3.	Sowing	1180	1300	2480 (13.8)	1180	1300	2480 (13.0)	1200	1500	2700 (13.4)
4.	Seed	176	1430	1606 (9.0)	208	1373	1581 (8.3)	702	2000	2702 (13.4)
5.	FYM	1392	0	1392 (7.8)	1481	0	1481 (7.8)	1392	0	1392 (6.9)
6.	Fertilizer	450	950	1400 (7.8)	450	1275	1725 (9.0)	450	1375	1825 (9.1)
7.	Irrigation	350	1851	2201 (12.3)	350	2025	2375 (12.4)	350	2225	2575 (12.8)
8.	Weed/insect pest	852	918	1770 (9.9)	825	1012	1837 (9.6)	825	900	1725 (8.6)
9.	Harvesting	879	1046	1925 (10.7)	875	1575	2450 (12.8)	875	1500	2375 (11.8)
10.	Threshing	809	2100	2909 (16.2)	806	2100	2906 (15.2)	810	2000	2810 (14.0)
	Total			**17915**			**19108**			**20104**

b. Maize – mustard cropping system

Total working cost of maize-mustard cropping system incurred by small, medium and large categories of farmers are Rs 11,804, 12,070 and 13,918/ha, respectively (Table 4). It means that as the size of land holding increases, the farmers also increase the expenditure on crops due to more risk bearing capacity. All the category of farmers spend about 15% of the total working cost on the purchase of fertilizers. The money spent on purchase of newly developed high yielding variety seeds was quite unreasonable and indicate poor adoption of quality seed. The Government's intervention in creating infrastructural facilities coupled with the farmer's ability to use modern productive technologies thus play crucial roles. For the later to occur the flow of timely and need based credit to the farmers is an essential pre-requisite (Rajeev and Dev, 1998).

Disposal patterns of main and by-products of maize–wheat cropping system

a. Main product

Out of the total grain production of maize-wheat cropping system per farmer (41.43q), 37.3, 4.2 and 59.5 percent was

Table 4. Resource use patterns in maize - mustard cropping system adopted by different categories of farmers (Rs/ha).

S.	Operations/	Small			Medium			Large		
No.	inputs	Maize	Mustard	Total	Maize	Mustard	Total	Maize	Mustard	Total
1.	Ploughing	775	775	1550 (13.1)	700	700	1400 (11.6)	700	700	1400 (10.0)
2.	Planking	300	300	600 (5.1)	300	300	600 (5.0)	300	300	600 (4.3)
3.	Sowing	180	300	480 (4.1)	180	300	480 (4.0)	260	364	624 (4.5)
4.	Seed	169	183	352 (3.0)	150	168	318 (2.6)	230	260	490 (3.5)
5.	FYM	1369	0	1369 (11.6)	1700	0	1700 (14.0)	1960	0	1960 (14.1)
6.	Fertilizer	350	1275	1625 (13.8)	250	1375	1625 (13.5)	425	1745	2170 (15.6)
7.	Irrigation	0	938	938 (8.0)	0	880	880 (7.3)	0	943	943 (6.8)
8.	Weed/insect -pest	870	720	1590 (13.4)	1068	732	1800 (14.9)	940	1200	2140 (15.4)
9.	Harvesting	990	735	1725 (14.6)	1104	744	1848 (15.3)	966	817	1783 (12.8)
10.	Threshing	780	795	1575 (13.3)	684	735	1419 (11.8)	863	945	1808 (13.0)
	Total			**11804**			**12070**			**13918**

Figures in parantheses indicate per cent investment in given items used as food, seed and sold in the market by small category of farmers, respectively (Table 5). The disposal pattern by medium category of farmers was 28.1, 6.7 and 65.2 per cent respectively, whereas by large category, it was 22.6, 4.2 and 73.2 per cent respectively. About 66 to 75% of total grain produced was sold in the market to meet out the family expenditure by all categories of farmers (Table 5).

b. By-product

Out of the total fodder production of maize-wheat cropping system per farmer (65.84q), 96.8 percent was used as fodder and rest 3.2 percent was sold in the market by small category of farmers, respectively (Table-6b). The disposal pattern by medium category of farmers was 99.8 and 0.2 per cent, respectively where as by large category; it was 82.7 and 18.0 per cent respectively. It means more than 95 per cent of total fodder produced per farmer was consumed to feed the animals by small and medium categories of farmers. Data also showed that large farmers sold about 1/5th part of total fodder produced in the market due to surplus fodder available with them.

Table 5.Disposal patterns of main product of maize -wheat cropping system (q) under different categories of farmers.

S. No.	Main product	Small			Medium			Large			Grand total
		Maize	Wheat	Total	Maize	Wheat	Total	Maize	Wheat	Total	
1.	Grain production	17.37	24.06	41.43 (100.0)	32.00	35.00	67.00 (100.0)	39.71	44.20	83.91	192.34 (100.0)
2.	Used as food	6.88	8.56	15.44 (37.3)	9.80	9.00	18.80 (28.1)	9.00	10.00	19.00 (22.6)	53.24 (27.6)
3.	Used as seed	0.84	0.90	1.74 (4.2)	1.50	3.00	4.50 (6.7)	1.51	2.00	3.51 (4.2)	9.75 (5.1)
4.	Sold in market	9.65	14.60	24.25 (59.5)	20.70	23.00	43.70 (65.2)	29.20	32.20	61.40 (73.2)	129.35 (67.3)

Figures in parentheses indicate per cent value

Table 6. Disposal patterns of by-product of maize -wheat cropping system (q) under different categories of farmers.

S. No.	By-product	Small			Medium			Large			Grand total
		Maize	Wheat	Total	Maize	Wheat	Total	Maize	Wheat	Total	
1.	Straw production	28.46	37.38	65.84 (100.0)	47.70	51.20	98.90	59.00 (100.0)	68.00	127.00 (100.0)	292.11 (100.0)
2.	Used as fodder	27.46	36.28	63.74 (96.8)	47.50	51.20	98.70 (99.8)	53.30	50.80	104.10 (82.7)	266.91 (91.4)
3.	Sold in market	1.0	1.10	2.10 (3.2)	0.20	0.00	0.20 (0.2)	5.70	17.20	22.90 (18.0)	25.20 (8.6)

Figures in parentheses indicate per cent value

Average employment

Data presented in the Table 7 showed the number of days in an agricultural year a farmer got employment in crop production. Large category of farmers engaged for about 294 days/year in the crop production whereas, medium and small categories farmers are engaged for only 228 and 214 days/year, respectively. Data further revealed that female member of the farming family engaged about 8 days more than the male members in an agricultural year.

Other sources of income

Table 8(a) and 8(b) indicated the other sources of income obtained by different categories of farmers of zone IVa in addition to crop production. The other main sources of income was from raising of cow and buffalo on the farm. Data showed that net profit obtained from cow/ buffalo increases with the increase in size of land holdings as the

Table 7. Average employment per year (mandays)

Category	*Kharif*			*Rabi*			Total (*Kharif* + *Rabi*)		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Small	45.25	48.79	94.04	57.38	62.56	119.94	102.63	111.35	213.98
Medium	54.08	50.20	104.28	60.20	63.40	123.60	114.28	113.60	227.88
Large	57.67	66.67	124.34	81.60	87.77	169.37	139.37	154.44	293.81
Mean							118.76	126.46	

Table 8(a). Income from cow (Rs)

Categories wise	No. of cows	Expenditure per cow	Income per cow	Net profit per cow
Small	64 (48.1)	4222.50	7678.75	3456.25
Medium	27 (20.3)	4384.00	7724.00	3340.00
Large	42 (31.6)	5500.00	10250.00	4750.00
Total	**133**			

Figures in parentheses indicate per cent value

Table 8(b). Income from buffalo (Rs)

Categories wise	No. of buffaloes	Expenditure per buffalo	Income per buffalo	Net profit per buffalo
Small	138 (49.8)	8841.25	14591.25	5750.00
Medium	63 (22.7)	9768.00	15984.00	6216.00
Large	76 (27.4)	9773.33	17581.33	7808.00
Total	**277**			

Figures in parentheses indicate per cent value

large category of farmers have incurred more expenditure on feeding in the livestock and thereby obtained higher income. Further, small farmers are having more cows (48.1 %) and buffalo (49.8 %) than the medium and large farmers.

Production constraints

The details of abiotic constraints and their impact on different major crops yield is presented in Table 9. The study revealed that the productivity of maize (26.5 %) and clusterbean (11.0 %) reduced considerably due to delayed sowing (Table 41). Weeds caused severe reduction in yield of wheat by 18.7 per cent. Soil related problems have major effect on yields of mustard (13.7 %) and groundnut (13.3 %). The productivity of groundnut has also declined by 20.5 and 14.6 per cent, respectively due to diseases and insect-pests. The analysis showed that major portion of crop yield was lost due to severe production constraints, which need suitable corrective measures. Bastine and Nair (1989) also found that technical guidance, non availability of improved seeds, lack of knowledge and lack of suitable varieties and capital deficiencies were some of the constraint in the adoption of recommended technology. Minimum tillage besides, being economical, time saving and energy efficient also manages weeds, conserves soil along with its moisture and enables advance sowing time (Sen and Sharma, 2002).

Socio economic constraints

The details of socio-economic constraints influencing crop production have been analyzed and presented in table-10. The percent yield losses due to lack of irrigation facilities were

Table 9. Yield losses in major crops due to production constraints (%).

Crop	Diseases	Insects	Weeds	Delayed sowing	Soil related problems
Maize	4.2	15.8	12.8	26.5	8.5
Wheat	7.5	12.5	18.7	7.7	10.5
Mustard	4.6	8.4	4.3	0.9	13.7
Clusterbean	2.0	3.0	4.0	11.0	8.7
Groundnut	20.5	14.6	9.6	8.6	13.3

Table 10. Socio-economic constraints in crop production.

Crop	Per cent yield losses						
	Seed	Fert.	Irri.	Tech Knowledge	Storage	Labour	Marketing
Maize	16.2	14.7	19.2	16.6	9.6	-	2.3
Wheat	18.2	18.1	20.2	12.0	4.5	2.0	4.4
Mustard	18.0	7.5	17.5	11.0	2.3	-	5.7
Cluster bean	9.6	3.4	2.0	6.0	-	-	1.0
Groundnut	14.6	12.6	14.6	13.0	2.3	-	6.0

estimated up to 19.2 in maize, 20.2 in wheat, 17.5 in mustard and 14.6 in groundnut crops. Non-availability of newly developed high yielding variety seeds (9.6-18.2%) and imbalanced use of fertilizers (3.4-18.1%) were also major constraints considerably influencing yield of all major crops grown in Udaipur district. Lack of technical knowledge about the scientific and improved methods of cultivation of crops in the farming community influence the yields of maize, wheat, mustard, cluster-bean and groundnut by 16.6, 12.0, 11.0, 6.0 and 13.0 per cent respectively. The shortage of storage facilities, labour and marketing problems also adversely affected the income from the crops.

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PRODUCTIVITY, PROFITABILITY AND NUTRIENT REMOVAL OF RICE (*ORYZA SATIVA*)- MAIZE (*ZEA MAYS*) CROPPING SYSTEM AS INFLUENCED BY SITE SPECIFIC NUTRIENT MANAGEMENT

R.P. Sharma, R.N. Jha, S.K. Pathak, K.R. Raman, and N. Chattopadhyaya

Bihar Agricultural College, Sabour, Bhagalpur-813210.

Abstract

A field experiment was conducted during 2006-07 to 2007-08 at Bihar Agricultural College, Farm ,Sabour, Bhagalpur to study the effect of site- specific nutrient management (SSNM) on crop productivity, profitability and nutrient removal of rice (*Oryza sativa*) – maize (*Zea mays*) cropping system. The experiment comprised 10 treatment combinations, wherein farmer's fertilizer practice and state recommendation were compared with eight SSNM options. Pooled analysis revealed that application of 150 kg N,60 kg P_2O_5 ,100 kg K_2O in rice and maize and 40 kg S/ha in rice only resulted in significantly higher values of grain yields of hybrid rice (79.1 q/ha) , maize (90.5 q/ha), rice-equivalent yields (161.7 q/ha), net returns (Rs.70,955/ ha) and B:C ratio (1.53) as well as nutrient uptake by rice and maize crops over the farmer's practice, state recommendation and the treatments in which either of the P_2O_5 ,K_2O and S were omitted from fertilizer schedule. The optimum dose of P_2O_5 ,K_2O and S for rice as per regression equation worked out to the extent of 54.7, 89.6 and 69.9 kg/ha, respectively whereas, optimum doses of P_2O_5 and K_2O for maize were 78.4 and 89.4 kg/ha , respectively. Application of balanced dose of nutrients improved the organic carbon, available N, P_2O_5 and S contents of the soil. However, marginal decline in K-status from its initial level was also observed in all the treatments.

Key words: Site Specific Nutrient Management, Productivity, Profitability, Nutrient removal, Energetic, Rice-Maize system

Rice (*Oryza sativa*)-maize (*Zea mays*) is the most dominant cropping system in irrigated ecology of alluvial plains of Bihar. Both rice and maize are the most important cereal crops of Bihar having high yield potential (50-90 q/ha). The rice - maize system is an exhaustive cropping system, requiring higher quantum of nutrients. Its continuous cultivation over a longer period leads to nutrient deficiency. One of the major reasons for this nutrient deficiency in soil is low level of replenishments through inadequate nutrient supply causing negative nutrient balances in the soil on the other (Yadav *et al.,* 1998). Maintenance of soil fertility at healthy levels (supply of all nutrients in proportions matching with a crop's needs) is one of the key steps towards safeguarding high productivity on a sustained basis. To meet the large nutrient needs of rice-maize system, SSNM can facilitate the desired know how in an efficient and cost effective manner. Therefore, the present investigation was carried out for achieving maximum economic yields through site- specific nutrient management in rice-maize system.

Materials and Methods

A field experiment was conducted for two consecutive years from 2006-07 to 2007-08 on a fixed site at Bihar Agricultural College Farm, Sabour, Bhagalpur. The experimental soil was clay loam having pH 8.0 with organic carbon 0.47 %, available N 175.6 kg/ha, P_2O_5 31.10 kg/ha, K_2O 220.6kg/ha, S 22.0 kg/ha and available micronutrients were B 0.7, Cu 6.5, Fe 54.0, Mn 9.8 and

Zn 4.7 mg/kg. The experiment was laid out in randomized block design with 4 replications. Based over soil analysis report, the treatment comprising combinations of 150 kg N/ha along with 3 levels each of P_2O_5 (0, 30 and 60 kg/ha), K_2O (0, 50 and 100 kg/ha) in rice and maize crop and 4 levels of S (0, 20, 40 and 60 kg/ha) applied only in rice. The experiment comprised 10 treatment combinations, wherein Farmer's nutrient management practices (FP) and state recommendation (SR) were compared with eight site- specific nutrient management (SSNM) options ($SSNM_1$ to $SSNM_8$). In case of each of the nutrients applied, there had been an addition treatment in which it was not applied, so that its response could be calculated as per the missing plot techniques. The SSNM worked out to achieve a yield target of 9.0 t/ha in rice and 9.0 t/ha in maize was kept at 150 kg N, 60 kg P_2O_5 and 100 kg K_2O in rice and maize and 40 kg S only in rice. Succeeding maize received only N, P and K fertilizers, as to assess the carry over effect of secondary nutrient (Sulphur). Recommended doses of 100 kg N, 40 kg P_2O_5 and 20 kg K_2O/ha and 120 kg N, 75 kg P_2O_5 and 50 kg K_2O/ha were applied in rice and maize, respectively. A dose of 70 kg N, 30 kg P_2O_5 and 15 kg K_2O/ha and 100 kg N, 30 kg P_2O_5 and 20 kg K_2O/h was applied in rice and maize, respectively as farmer's fertilizer practice treatments. The crops in all the plots were raised under optimum conditions. Apart from differences in nutrient application rates, all other practices were the same for SSNM, SR and farmer's practice. N, P, K and S were applied in the form of urea, diammonium phosphate, muriate of potash and elemental sulphur. Hybrid rice variety PHB-71 was transplanted by 1st week of July at a spacing of 20 x 10 cm and maize variety Shaktiman-3 was sown in last week of November with a spacing 60x20 cm. The hybrid rice was harvested in the last week of October and maize was harvested in the 2nd week of May. The prevailing market price of different commodities was used to work out the rice-equivalent yield and economics of the system. The data of 2 years were pooled and subjected to statistical analysis. Nutrient uptake of N, P,K and S by plants were computed using standard procedures. After harvesting, separate soil samples were collected from each plot for estimation of organic carbon, available N, P, K and S.

Results and Discussion

Grain yield of rice and maize

Among the three nutrients management options tried in the study, SSNM proved significantly superior to farmers practice and state recommendations. Application of 150 kg N, 60 kg P_2O_5, 100 kg K_2O in both rice and maize and 40 kg S/ha only in rice recorded the highest grain yields of hybrid rice (79.1 q/ha), maize (90.5 q/ha) system productivity (169.6 q/ha) and rice-equivalent yield (161.7 q/ha), which brought an improvement of 28.8 q/ha in rice ,22.6 q/ha in maize, 51.8 q/ha in system productivity and 49.5 q/ha in rice-equivalent yield over farmer's practice . The magnitude of such advantage over state recommendation were 16.4, 13.2, 29.6 and 29.7 q/ha, respectively (Table 1). Omission of any of the nutrient (P_2O_5 and K_2O in rice and maize and S in rice) in spite of application of 150 kg N /ha and also the rest of nutrients , grain yields of rice and maize as well as rice-equivalent yield decreased significantly than that recorded under the treatment giving the highest yield ($SSNM_6$). Significant yield advantage under SSNM treatments may be due to the application of higher amounts of nutrients might have increased the availability of nutrients in root zone and thus greater uptake of nutrients by plants resulted in higher grain production. Regmi and Ladha (2004) also reported significant increase in yield of rice- wheat through SSNM over local management practice

Effect of P_2O_5

Rice responded significantly only up to 30 kg P_2O_5 /ha whereas maize responded significantly up to 60 kg P_2O_5 /ha. (Table 1). Application of 60 kg P_2O_5/ ha in both the crops increased the yield of rice , maize and rice-equivalent yield by 13.3, 18.0 and 29.8 q/ha over the crop raised without P-applications . The possible reason for increase in grain yields with phosphorus fertilizers could be attributed to the fact that phosphorus plays a key role in root development. The increased root bio-mass might have improved the nutrient-uptake by exploiting greater volume of soil resulting in better physiological and metabolic functions inside the plant body which in turn laid down the foundation of higher yields in both the crops. Sharma *et al.* (1998) also reported the similar results in rice- wheat system.

Effect of K_2O

Significant response in grain and straw yields of rice and maize were recorded with the application of 50 kg K_2O/ha. Application of 50 kg K_2O/ha ($SSNM_4$) gave 10.6, 11.4 and 21.0 q/ha additional yield of rice, maize and rice-equivalent yield over no K- application. Increasing dose beyond 50 kg K_2O /ha could not bring any significant yield advantage. Higher yields under K application was ascribed to increasing photosynthetic activities , resulting higher production of photosynthates and their translocation to sink , which might have directly contributed towards the better yield. The increase in grain yield with increasing rates of K application has been reported by Tiwari (2002).

Effect of Sulphur

Application of gradient of S (0, 20, 40 and 60 kg/ha) in rice and their residual effect on maize brought a linear increase in productivity of rice and maize crop but the responses were significant only up to 40 kg/ha (Table 1). At this application rate, rice and maize crop had 8.6 and 5.3 q/ha yield gain at the rate of 12.7 and 6.6 %, respectively over no S-application. The increase in grain yield of wheat with residual effect of S-application was also reported by Singh *et al.* (2005). This could be attributed to the fact that S application improved nutritional environment of rhizosphere as well as nutrient uptake and ultimately metabolic and photosynthetic activities, resulting in better yield of both the crops

Economics

Economic analysis of data revealed that the highest net returns of Rs.70,955 /ha from the rice-maize system was realized with the application of 150 kg N + 60 kg P_2O_5 + 100 kg K_2O /ha in both the crops and 40 kg S/ha only in rice, which, however, was at par with those treatments which got 150 kg N along with 30 kg P_2O_5 and 100 Kg K_2O/ha and 40 or 60 kg S ($SSNM_6$ & $SSNM_1$). The highest economic return giving treatment ($SSNM_2$) earned an additional income of Rs.29,291 /ha and Rs.16,829 /ha over the farmers' practice and state recommendation, respectively. The treatment showing the highest net return also had the highest B: C ratio (1.53). The farmer's practice had the

Table 1. Effect of site specific nutrient management on grain, straw, rice-equivalent yields and economics of rice and maize (mean of 2 years)

Treatment	Nutrients (kg/ha)				Grain yield (q/ha)		Increase over S.R. (q/ha)		Straw/stover yield (kg/ha)		System (q/ha)	REY (q/ha)	Cost of cultivation (Rs./ha)	Net returns (Rs./ha)	B:C ratio
	N	P_2O_5	K_2O	S*	Rice	Maize	Rice	Maize	Rice	Maize					
$SSNM_1$	150	30	100	40	76.23	84.21	21.6	8.9	99.81	141.20	160.44	153.14	45,193	65,490	1.45
$SSNM_2$	150	60	100	40	79.05	90.54	26.1	17.1	103.32	151.86	169.59	161.72	46,450	70,955	1.53
$SSNM_3$	150	0	100	40	65.74	72.49	4.9	-6.2	90.25	122.21	138.23	131.95	43,940	52,581	1.20
$SSNM_4$	150	30	50	40	73.51	81.31	17.3	5.2	96.92	137.00	154.82	147.78	44,423	63,034	1.42
$SSNM_5$	150	30	0	40	62.95	69.89	0.4	-9.6	86.59	118.84	132.84	126.78	43,653	49,112	1.13
$SSNM_6$	150	30	100	60	77.76	85.99	24.1	11.2	101.86	144.65	163.75	156.31	45,543	67,847	1.49
$SSNM_7$	150	30	100	20	70.97	80.60	13.2	4.3	95.58	136.72	151.57	144.59	44,593	59,935	1.34
$SSNM_8$	150	30	100	0	67.63	78.93	7.9	2.12	93.30	134.13	146.56	139.79	43,993	58,148	1.32
S.R.	100(120)	40(75)	20(50)	0	62.67	77.30	-	-	88.20	129.67	139.97	132.04	43,487	54,126	1.24
F.P.	70(100)	30(30)	15(20)	0	50.28	67.88	-	-	76.49	118.12	118.16	112.23	41,468	41,664	1.00
		SEm±			1.78	1.98	-	—	2.03	3.35	-	2.68	-	1,997	0.04
		CD(P=0.05)			**5.14**	**5.71**	**-**	**-**	**6.08**	**9.71**	**-**	**7.76**	**-**	**5,789**	**0.12**

*Sulphur was applied to rice only, F.P. - Farmer's fertilizer practice, SR – State recommendation, REY- rice-equivalent yield.

lowest profitability (Rs.41,664 /ha). It was also noted that skipping P_2O_5 from the fertilizer schedule caused highest reduction in profitability (Rs 21,843 /ha/ year), followed by K_2O (Rs 16,378/ha) and S (Rs 7,912/ha).Thus, balancing N, P, K with S is necessary for profit maximization.

Nutrient uptake

The application of 150kg N, 60 kg P_2O_5, 100 kg K_2O/ha in rice and maize and 40 kg S/ha only in rice resulted in significantly higher N, P,K and S uptake by rice and maize crops over farmer's practice, state recommendation and the treatment in which either of the P_2O_5,K_2O and S were skipped from fertilizer schedule (Table 2). The application of fertilizers as per crop's needs increased its uptake by rice and maize owing to fertilizer application might have improved the availability of nutrient in the soil which led to increased nutrient content in the plant and ultimately uptake.

Increasing levels of P_2O_5 and K_2O in rice and maize S in rice enhanced the P,K and S uptake by crops significantly up to 60 kg P_2O_5, 50 kg K_2O and 40 kg S /ha which increased its uptake by 30.9,19.7 & 26.1% in rice and 39.5, 19.2 and 22.7 % in maize, respectively over their control. This increase in P,K and S uptake by crops can be ascribed to the influence of applied P_2O_5 ,K_2O and S on availability of nutrients in the soil as well as in view of prolific root system developed by balanced nutrient application giving rise to better absorption of water and nutrient. Moreover, the uptake followed the pattern of yield. These results are in close conformity with the findings of Viravipour et al (1999)

Total N,P and K uptake data (Table 2) also revealed that in the process of producing 169.6 q/ha grain with the application of 150 kg N,60 kg P_2O_5 and 100 kg K_2O /ha in rice and maize and 40 kg S/ha only in rice-maize system absorbed 907.9 kg N + P_2O_5 + K_2O. This value was composed of 38.8 % N, 13.4% P_2O_5 and 47.8% K_2O in a proportion of 100:35:123. On an average to produce a tonne of grain, rice absorbed 18.7 kg N,6.9 kg P_2O_5 and 24.2 kg K_2O, the corresponding figures for maize being 22.6 kg N, 7.4 Kg P_2O_5 and 26.8kg K_2O/ ha. In addition to N,P and K the rice-maize system absorbed 88.6 kg S/ha. Out of the total NPK uptake the share of rice was 43% and that of maize was 57%. The greater share of maize was primarily due to its higher productivity. Similar results were reported by Tiwari and Sharma (2006).

Response functions:

Response to P, K and S were quadratic, indicating the operation of the law of diminishing return.

Phosphorus: Rice: $Y= 65.74 + 0.48 X- 0.0043 X^2$

Maize: $Y=72.49 + 0.48 X - 0.0030 X^2$

Potassium: Rice: $Y = 62.95 + 0.29 X- 0.0016 X^2$

Maize: $Y=69.89 + 0.31X – 0.0017 X^2$

Sulphur: Rice: $Y= 67.35 + 0.25 X - 0.0011 X^2$

Where Y, Grain yield (q/ha); X , dose of specific nutrient.

As per above equations, the optimum dose of P_2O_5, K_2O and S for rice were worked out to be 54.7, 89.6 and 69.9 kg/ ha, respectively. The corresponding values of optimum yield were 79.1, 76.3

Table 2. Nutrient uptake (kg/ha) by rice and maize as influenced by site specific nutrient management (mean of 2 years)

Treatment	Nutrient (kg/ha)				Nutrient uptake (kg/ha)											
					Rice				Maize				Rice-maize system			
	N	P_2O_5	K_2O	S	N	P_2O_5	K_2O	S	N	P_2O_5	K_2O	S	N	P_2O_5	K_2O	S
$SSNM_1$	150	30	100	40	141.4	51.6	185.4	33.8	189.4	59.8	226.1	49.7	330.8	111.4	411.5	83.5
$SSNM_2$	150	60	100	40	147.9	54.6	190.7	34.9	204.4	67.4	242.9	53.7	352.3	122.0	433.6	88.6
$SSNM_3$	150	0	100	40	123.6	41.7	164.4	28.8	161.7	48.3	194.0	43.3	285.3	90.0	358.3	72.1
$SSNM_4$	150	30	50	40	140.1	49.4	171.2	32.9	183.4	56.1	208.7	48.4	323.4	105.4	379.9	81.2
$SSNM_5$	150	30	0	40	120.2	42.7	137.6	28.1	157.5	49.0	175.1	41.6	277.6	91.7	312.6	69.7
$SSNM_6$	150	30	100	60	146.7	53.9	189.5	35.9	195.3	61.6	228.6	50.5	342.0	115.4	418.0	86.3
$SSNM_7$	150	30	100	20	136.3	48.0	173.1	31.0	180.2	58.2	218.7	45.8	316.5	106.2	391.8	76.8
$SSNM_8$	150	30	100	0	129.9	46.7	166.5	26.8	177.2	56.4	212.7	40.5	307.0	103.1	379.1	67.2
S.R.	100(120)	40(75)	20(50)	0	113.7	43.8	147.8	24.4	158.8	55.9	192.3	39.4	272.4	99.7	340.0	63.8
F.P.	70(100)	30(30)	15(20)	0	90.1	34.9	120.3	19.6	136.1	45.1	167.2	33.8	226.2	80.0	287.4	53.4
		SEm±			3.2	1.2	4.0	0.8	4.7	1.4	5.9	1.1	5.8	1.9	7.1	1.4
		CD (P=0.05)			**9.2**	**3.4**	**11.6**	**2.2**	**14.0**	**4.0**	**17.0**	**3.2**	**16.7**	**5.4**	**20.6**	**4.0**

and 80.3 q/ha, respectively. The optimum dose of P_2O_5 and K_2O for maize were also calculated, which were 78.4 and 89.4 kg/ha and their corresponding yield were 91.8 and 84.3 q/ha, respectively. As compared to the state recommendation of 20 and 50 kg /ha for rice and maize developed long back, the computed value of K_2O requirement for rice and maize were much higher. The P_2O_5 doses under recommendation are close to that worked out under this experiment. At present S application is not recommended and to be essential for increasing crop productivity of rice-maize system.

Energetics

The highest energy input (56,230 MJ/ha) and energy output (5, 68,259 MJ/ha) was realized with the application of 150 Kg N + 60 Kg P_2O_5 + 100 Kg K_2O to both rice and maize and 40 Kg S/ha only to rice, which showed statistical parity with the treatment receiving 150 Kg N + 30 Kg P_2O_5 + 100 Kg K_2O to both rice and maize and 60 Kg S/ha to rice only (Table 3). The Higher energy output in these treatments was mainly due to higher yield of crops. The treatment giving the highest energy output ($SSNM_2$) also showed the highest energy output: input ratio (10.1) as well as energy productivity (301.6 g/MJ) and the lowest specific energy (331.6 MJ/q).

Fertility status of soil

Application of balanced dose of nutrients in rice and maize was helpful in improving organic carbon, available N and P_2O_5 contents of the soil (Table 4). However, organic carbon, available N and P content slightly reduced in farmer's fertilizer practice when compared with initial value. Although, the variation was very marginal. A

Table 3. Energetics as influenced by site specific nutrient management (mean of 2 years)

Treatment	Nutrients(kg/ha)				Energy Input (MJ/ha)	Energy Output (MJ/ha)	Energy output: input ratio	Specific energy (MJ/q)	Energy productivity (g/MJ)
	N	P_2O_5	K_2O	S*					
$SSNM_1$	150	30	100	40	55,564	5,37,096	9.7	346.3	288.7
$SSNM_2$	150	60	100	40	56,230	5,68,259	10.1	331.6	301.6
$SSNM_3$	150	0	100	40	54,898	4,68,766	8.5	397.2	251.8
$SSNM_4$	150	30	50	40	54,894	5,19,973	9.5	354.6	282.0
$SSNM_5$	150	30	0	40	54,224	4,52,056	8.3	408.2	245.0
$SSNM_6$	150	30	100	60	55,982	5,48,843	9.8	341.9	292.5
$SSNM_7$	150	30	100	20	55,146	5,13,176	9.3	363.8	274.8
$SSNM_8$	150	30	100	0	54,728	4,99,731	9.1	373.4	267.8
S.R.	100(120)	40(75)	20(50)	0	49,620	4,78,080	9.6	354.5	282.1
F.P.	70(100)	30(30)	15(20)	0	45,711	4,16,944	9.1	386.9	258.5
		SEm±			-	9,025	0.2	6.1	4.3
		CD(P=0.05)			-	**26,292**	**0.5**	**17.4**	**13.2**

Table 4. Effect of site-specific nutrient management on fertility status of soil.

Treatments	Nutrients (kg/ha)				Organic carbon (%)	Available Nutrients (Kg/ha)			
	N	P_2O_5	K_2O	S		N	P_2O_5	K_2O	S
$SSNM_1$	150	30	100	40	0.53	185.2	34.20	210.4	22.20
$SSNM_2$	150	60	100	40	0.54	183.3	39.41	208.2	22.53
$SSNM_3$	150	0	100	40	0.51	197.5	26.82	212.3	23.82
$SSNM_4$	150	30	50	40	0.52	185.7	35.23	204.5	23.65
$SSNM_5$	150	30	0	40	0.51	194.8	34.35	199.6	24.26
$SSNM_6$	150	30	100	60	0.54	186.8	35.91	207.6	26.10
$SSNM_7$	150	30	100	20	0.52	188.5	35.75	209.7	22.70
$SSNM_8$	150	30	100	0	0.51	190.2	36.82	210.6	18.65
S.R.	100(120)	40(75)	20(50)	0	0.50	173.6	38.35	205.4	18.31
F.P.	70(100)	30(30)	15(20)	0	0.46	165.7	30.50	203.7	17.65
Initial value					**0.47**	**175.6**	**31.10**	**220.6**	**22.00**

S.R. – State recommended dose (SRD); F.P.- Farmers practice

marginal decline in K-status from its initial level was also observed in all the treatments. Application of balanced dose of nutrients maintained the initial level of sulphur, of the soil. The treatments in which P or K or S were skipped showed reduction in available P, K and S content in the soils.

On the basis of results, it can be inferred that application of 150 kg N + 30 kg P_2O_5 + 50 kg K_2O + 40 kg S/ha in rice and 150 kg N + 60 kg P_2O_5 + 50 kg K_2O/ha in maize were found optimum for maximization of productivity and profitability without deteriorating the fertility of soil of rice – maize cropping system.

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WATER USE EFFICIENCY OF MINOR IRRIGATION SOURCES IN CULTIVATION OF CROPS UNDER RAINFED RICE FARMING SITUATION OF BILASPUR DISTRICT (C.G.)

A.K. Koshta[1] and R.K. Mishra[2]

[1]*Scientist (Agril. Economics), Directorate of Research Services, Raipur*
[2] *Senior Scientist (Agronomy), RMD CoA & Research Station, Ambikapur,*
Indira Gandhi Krishi Vishwavidyalaya, Raipur - 492006 (C.G.)

Abstract

The study revealed that owners of TW up to 5 HP and above 5 HP SMP acquired more assets (excluding land) as compared to the owner of other minor irrigation sources. Owners of TW with combination to other minor irrigation sources needed more fund for agricultural operations. The different water lift equipments used under minor irrigation sources and their discharge of water was 0.553, 0.430, 0.424 and 0.375 ha. cm / hour through TW above 5 HP SMP, electric centrifugal pump, (ECP), TW up to 5 HP SMP and diesel pump (DP), respectively. The total cost of water discharge was Rs. 26.50 per hour and the cost of 1 ha. cm of water was Rs. 73.14 in case of DP, which was found to be the maximum. However, it was Rs. 27.28, Rs. 21.84, and Rs. 9.60 cost for 1 ha. cm. of water discharge through TW up to 5 HP SMP, TW above 5 HP SMP and ECP, respectively. The use of irrigation water by the owners to their own farm fields and for sale to other farm fields was noted to be 987, 502, 219, 152, 150, 127 and 115 ha. cm. water from TW above 5 HP SMP, TW + R (ECP), TW + T (SMP), respectively. The sale of water to other farms was comparatively more in reservoir (R) and TW + R through DP whereas, it was the minimum in case of TW irrigation source. The water use efficiency was poor in summer paddy in all the sources of irrigation; it was due to providing excess water from TW source. To control the exploitation of ground water summer paddy should be replaced with low water requirement crops. Electricity charges should be fixed in rational manner in place of nominal rates. The state government is provided the subsidy to the farmers for digging the TW, Well Dabhri (small pond) under different programmes, it is therefore, provision should be made to given the minimum subsidy should be give in case of success the bore (TW) and the maximum subsidy should be provided in case of failure of bore. The state government does not have concrete plan for strengthening the minor irrigation sources, It is therefore, a solid plan should be developed to control the exploitation of ground water is particular and in general for minor irrigation sources.

Key wards: Water Use Efficiency, Minor Irrigation Sources, Optimum Use of Water lift Equipment and Utilization of Minor Irrigation Sources

Water is prime input for crop production and it is available from the major, medium and minor irrigation sources. These irrigation sources contributed 26 per cent irrigation to the total cropped area of Chhattisgarh state. Under the major irrigation sources, canal irrigation shared 21 percent. The main constraint of canal irrigation source is non-availability of water as and when required to the crops and also irrigation is not available to the crops even at the time of water stress condition developed in crops. In consequence of this, government is giving more emphasis for the development of minor irrigation sources as in the form of tube-well, well, tank and reservoir. The minor irrigation sources have potential of assured irrigation as per requirement to the crops. Utilization of underground water is free in the state and it depleted very fast by over utilization. So, the utilization of ground water requires precautionary measure for their use as ground water is most scarce resource at present. For ensuring the more productivity of crops, the optimum use of water is most essential. In view of this a present study has been undertaken with the following specific objectives:

Objectives:

- To examine the pattern of investment on minor irrigation sources.
- To estimate the discharge of water and cost of irrigation for the unit requirement of water to the crops from different water lift equipments used under the minor irrigation sources.
- To examine the pattern of utilization of minor irrigation sources.
- To estimate the optimum water requirement of crops through water lift equipments used under minor irrigation sources.
- To suggest the policy implications for utilization of ground water.

Materials and Methods

Dabhra block of Bilaspur district was selected purposively for the study as block has noticed the maximum area under minor irrigation sources. From the 126 villages of Dabhra block, a list of the tube-well owners was prepared from the Patwari Records. These villages were categorized into three groups in accordance to number of tube-wells viz; up to 2, above 2 to 4 and above 4. From the categorized villages, 2 villages for each first and second category and 3 villages for third category were considered. Despite of that one village for tank and one village for reservoir source were included. So, the total 9 villages were for the study. These nine villages were Bilaigarh, Seroli, Kotmi, Kutod, Borsi, Patialih, Saraipali, Barhaguna and Kosmanda. Fifty per cent farmers were taken in consideration. Totally, 77 farmers were selected for all the sources of minor irrigation amongst them 33, 14, 12, 6, 4, 5 and 3 farmers were users for tank (T), tube-well (TW), reservoir (R), well (W), tube-well & reservoir (TW + R), tube-well & tank (TW + T) and others & tank (O + T) irrigation sources, respectively. The primary data were collected on schedule design for the study in all relevant aspects pertaining to the year 2003-04.

The data were analyzed by using simple average and percentage method.

To estimate the discharge of water lift equipments used in minor irrigation sources, a coordinate method was used. The formula of coordinate method as under:

$$Q = \frac{c \cdot a \cdot x \cdot \sqrt{g}}{\sqrt{2y}}$$

Where, Q= discharge in m^3/sec.

c= co-efficient of discharge=1

a= cross section area of pipe in m^2

x= x-coordinate in m.

y= y-coordinate in m.

g= acceleration due to gravity 9.81 m/ s^2

Submersible pump (SMP), electric centrifugal pump (ECP) and diesel pump (DP) were used to lift the water from minor irrigation sources and their discharge was estimated in ha. cm. The cost of water discharge of SMP, ECP and DP was worked out on fixed and variable costs components (fixed cost includes the depreciation & interest on working capital and variable cost includes the repair & maintenance, electricity charges & wage payment to the labours).

The break-even analysis was worked out for optimum use of water lift equipments used in minor irrigation sources. For this total cost, total revenue collected from water sale and annual discharge of different water lift equipments.

The exploitation of ground water for cultivation of summer paddy was the matter of discussion to policy makers. So, the optimum quantity of water applied to the crops was computed with the total quantum of water required to the crops and actual quantity of water applied to the crops.

Results & Discussion

This study yields many useful results and it is presented on the following heads:

Pattern of Farm Investment by Owners of Minor Irrigation Sources:

Farm investment pattern gives insight picture of the sample farmers and it is presented in Table 1. It reveals that farmers under TW (up to & above 5 HP) irrigation sources invested more for acquiring the assets (excluding the land) than that of the farmers under tank (T), well (W) and reservoir (R) sources of irrigation. The investment made by the farmers for acquiring assets was the

Table 1. Pattern of farm investment by irrigation source.

(in Rs/farm)

Minor Irrigation sources	Land	Livestock	Power/machine Operated Equipments	Hand & Bullock Operated Equipments	Total
TW upto 5 HP SMP	550133 (80.55)	28560 (4.18)	96533 (14.13)	7758 (1.14)	682984 (100)
TW above 5 HP SMP	664800 (58.75)	28680 (2.53)	217200 (19.20)	3594 (0.32)	1131474 (100)
Well (W)	182600 (82.78)	11960 (5.42)	16600 (7.52)	9434 (4.28)	220594 (100)
Reservoir (R)	153200 (86.50)	11060 (6.24)	8000 (4.52)	4846 (2.74)	177106 (100)
Tank (T)	1579092 (98.96)	11047 (0.69)	473 (0.03)	5106 (0.32)	1595718 (100)
TW + R	751800 (79.42)	36900 (3.90)	156450 (16.53)	1420 (0.15)	946570 (100)
TW + T	308400 (61.26)	24480 (4.86)	156404 (31.06)	14207 (2.82)	503491 (100)
O + T	340400 (90.36)	21000 (5.57)	5600 (1.49)	9709 (2.58)	376709 (100)

Note: ( ) denotes the percentage to the total investment.
The valuation of farm assets has been done at current market price prevailed in the study area.
Power / machine operated equipments include the water lift equipments.

maximum under TW above 5 HP irrigation sources followed by TW + T, TW + R, TW up to 5 HP, tank (T), O + T, reservoir (R) and well (W) sources of irrigation, respectively. It indicates that owners of TW and their combination with other irrigation sources required more fund for agricultural operations. More land was noticed to the farmers under tank irrigation source followed by reservoir and well irrigation sources which was found to be 98.96, 86.50 and 82.78 per cent respectively. Livestock were ranging from 4 to 5 animals, irrespective to irrigation sources except tank irrigation source. Comparatively more investment was noticed on power/ machine operated equipments by the farmers of TW and less investment on hand/bullock operated equipments. Farmers under well irrigation source invested more funds on hand/bullock-operated equipments.

Discharge of Irrigation Water by Water Lift Equipments and Irrigation Cost:

The discharge of water from water lift equipments used under minor irrigation sources is computed on hectare centimeter per hour (ha. cm./hr) and it is presented in Table 2. The discharge of water lift equipments was 0.553, 0.430, 0.424 and 0.375 ha. cm./hr through TW above 5 HP SMP, ECP, TW up to 5 HP SMP and DP, respectively. The quantity of water discharge might not be a criterion for choosing the water lift equipments for irrigation whenever the cost of per ha. cm. water is not included. So, the costs of water discharge per ha. cm. has been computed and it is given in Table 3. The total cost per hour and total operating cost per ha. cm. of water discharge was the maximum under DP and it was found to be Rs. 26.50 per hour and Rs. 73.14 per ha. cm. water, respectively. Tube- well up to 5 HP SMP and ECP discharged nearly the same volume of water. But the cost of water per ha. cm. was very low in ECP than that of cost of water discharge per ha. cm. of TW up to 5 HP SMP. The per hour cost of water was noticed to be Rs. 12.08, Rs. 11.56 and Rs. 4.13 under TW above 5 HP SMP, TW up to 5 HP SMP and ECP, respectively. The total operating cost for 1 ha. cm. of water was Rs. 27.28, Rs. 21.84 and Rs. 9.60 under TW up to 5 HP SMP, TW above 5 HP SMP and ECP, respectively. The break-even analysis was carried out for optimum hour of utilization annually of water lift equipments. The cost per hour of water discharge, revenue collected after selling of water and annual discharge of water in hours were considered for computation of break-even analysis and it was noted to be 183, 184, 122, 178 hours of utilization of TW up to 5 HP SMP, TW above 5 HP SMP, DP and ECP, respectively was profitable. It implies that if hours of utilization of water lift

Table 2. Discharge of water through water lift equipments.

Particulars	Cross Section Area of Pipe (a) in sq.m.	Length of Coordinate Pipe (y) in m.	Length of Coordinate Pipe (x) in m.	Discharge of Water in m^3/min	Discharge of Water (ha.cm/ hr)
TW upto 5 HP SMP	0.00458	1.22	1.29	0.708	0.424
TW above 5 HP SMP	0.00528	0.85	1.21	0.923	0.553
ECP	0.00458	1.05	1.21	0.718	0.430
DP	0.00458	0.78	0.91	0.626	0.37

Table 3. Cost of Irrigation under Different Lift Equipments.

Particulars	Fixed Cost (in Rs./hr)			Operating Cost (in Rs./hr)				Total Cost (in Rs./hr.)	Operating Cost of Water (ha. cm.)
	Depreciation	Interest	Total	Repair & Maintenance	Electricity Charge	Wage to labour	Total		
TW upto 5 HP SMP	3.12	2.86	5.98	3.12	0.96	1.50	5.58	11.56	27.28
TW above 5 HP SMP	2.90	2.65	5.55	2.90	2.13	1.50	6.53	12.08	21.84
ECP	0.54	0.50	1.04	0.54	1.05	1.50	3.09	4.13	9.60
DP	0.78	0.71	1.49	0.78	22.71	1.50	25.00	26.50	73.14

equipments below to the break even point farmers will suffer in loss.

Water Utilization:

Water lift equipments namely SMP up to 5 HP, SMP above 5 HP, ECP and DP were used for lifting the irrigation water under different minor irrigation sources. The owners of minor irrigation sources were utilizing the irrigation water for their own field crops as well as crops of neighbour fields of non-owners' minor irrigation sources. (see Table 4). It reveals that annual utilization of TW, W, R, TW + R, TW + T and O + T was 1206.1, 74.6, 242.7, 697.7, 152.5 and 28 ha.cm. irrigation water, respectively. Water sale was prominent in the total utilization of minor irrigation sources. Irrespective to the water lift equipments, it was noted to be 162.2, 10.5, 140.2, 112.2, 81.6 and 10 ha. cm. of water sale to neighbour fields, which was 13.4, 14.1, 57.8, 16.1, 53.5 and 35.7 per cent to the total utilization of respective minor irrigation sources. The water sale was the maximum through DP under reservoir and TW + R irrigation sources, which was noted to be 67. 53 per cent and 57.37 per cent water sale of respective minor irrigation sources. The owners of DP under the reservoir source were selling more water to other fields than that of own farm use. While, owners of TW above 5 HP SMP were using proportionately more water for their own farms use and it was noted to be 92.27 per cent irrigation water. Water sale from TW up to & above 5 HP SMP and TW + T were noted to be more for cultivation of summer paddy. The water sale from DP, ECP and TW + R under reservoir source was more for cultivation of wheat. Notable water sale was also observed under TW + R (33.9 ha. cm.) in cultivation of kharif paddy. It is interesting to note that more quantity of water sale was observed through DP under reservoir irrigation source than that of own farm use. The owner of DP have opportunities to earn additional income by selling of irrigation water subject to condition of that reservoir should have sufficient water.

Table 4. Utilization of irrigation water by source and water Lift Equipment.

(in ha.cm./farm)

Minor Irrigation Source	Water Lift Equipment	Kharif		Rabi				Summer				Total of Rabi & Summer		Total of All Seasons		Grand
		Paddy		Mustard		Wheat		Paddy		Groundnut						
		Own Use	Sale to other farms	Own Use	Sale to other farms	Own Use	Sale to other farms	Own Use	Sale to other farms	Own Use	Sale to other farms	Own Use	Sale to other farms	Own Use	Sale to other farms	
Tube-well	Up to 5HP SMP	14.4	16.5	0.7	0.2	69.5	16.5	47.4	52.3	1.2	-	118.0	68.8	133.3	85.3	218.6
	Above 5HP SMP	97.9	27.7	-	-	588.4	11.1	224.3	38.2	-	-	812.7	49.2	910.6	76.9	987.5
Well	DP	2.7	1.3	0.9	3.4	-	-	4.4	-	2.6	3.4	7.0	3.4	14.1	4.7	18.8
	ECP	-	-	0.4	7.2	32.3	-	7.0	4.7	3.2	-	42.4	4.7	50.0	5.8	55.8
Reservoir	DP	3.6	9.2	1.5	-	25.9	57.0	8.5	19.3	1.6	-	36.0	76.3	41.0	85.5	126.6
	ECP	3.1	1.8	-	-	52.0	43.5	4.7	9.3	0.7	-	57.3	52.9	60.5	54.7	115.1
TW + R	TW SMP	74.7	33.9	-	-	324.4	31.8	11.1	21.2	3.2	-	338.7	53..00	415.1	86.9	502.0
	DP	8.8	14.1	-	-	-	-	8.9	11.3	1.1	-	10.0	11.3	18.8	25.3	44.1
	ECP	17.2	-	-	-	134.4	-	-	-	-	-	134.4	-	151.6	-	151.6
TW + T	TW SMP	-	-	-	-	40.3	37.3	27.6	44.3	0.3	-	68.2	81.6	68.2	81.6	149.8
	DP	-	-	2.3	0.5	-	-	-	-	-	-	-	-	2.7	-	2.7
O + T	DP	6.8	10.0	-	-	-	-	11.3	-	-	-	11.3	-	18.0	10.0	28.0

Table 5. Added cost & return with the purchase of water by source and water lift equipment.

(in Rs/ha/farm)

Minor Irrigation Source	Water Lift Equipment	Kharif			Rabi						Summer					
		Paddy			Mustard			Wheat			Paddy			Groundnut		
		Added Yield (in q/ha)	Added Cost	Added Return	Added Yield (in q/ha)	Added Cost	Added Return	Added Yield (in q/ha)	Added Cost	Added Return	Added Yield (in q/ha)	Added Cost	Added Return	Added Yield (in q/ha)	Added Cost	Added Return
Tube-well	Up to 5HP SMP	3.94	450	1970	1.88	7	2256	1.02	450	816	12.22	1427	6110	-	-	-
	Above 5HP	5.45	604	2725	-	-	-	0.69	242	552	8.70	833	4350	-	-	-
Well	DP	0.33	91	165	1.17	252	1404	-	-	-	-	-	-	0.15	252	210
	ECP	-	-	-	1.35	69	1620	-	-	-	0.83	45	415	-	-	-
Reservoir	DP	2.95	674	1475	-	-	-	2.86	4117	2288	3.22	1408	1610	-	-	-
	ECP	0.42	17	210	-	-	-	2.24	418	1792	1.75	89	875	-	-	-
TW + R	TW SMP	8.00	925	4000	-	-	-	1.71	868	1368	3.00	578	1500	-	-	-
	DP	4.38	1028	2190	-	-	-	-	-	-	3.88	823	1940	-	-	-
TW + T	TW SMP	-	-	-	-	-	-	2.11	1018	1688	6.50	1207	3250	-	-	-
	DP	-	-	-	0.78	33	936	-	-	-	-			-	-	-
O + T	DP	3.08	731	1540	-	-	-	-	-	-	-			-	-	-

Added Cost & Return with Purchase of Irrigation Water:

The added cost and return of summer paddy by purchased of irrigation water under different minor irrigation sources has been estimated and presented in Table 5. It was found that summer paddy gave comparatively more added net return to the farmers by purchase of irrigation water under TW up to & above 5 HP SMP irrigation sources

than that of kharif paddy. All the crops were profitable except wheat and summer groundnut by purchase of irrigation water through DP (diesel pump) under reservoir (R) and well (W) irrigation sources. It was due to purchase of irrigation water through DP was costlier. It reflects that purchasing of irrigation water was not a bad idea for low water requirement crops in rainfed farming situation.

Optimum use irrigation water:

It is always a matter of discussion among the policy makers that summer paddy requires more quantity of water which is not desirable for ground water. So, the water use efficiency of summer paddy and other crops under minor irrigation sources was measured and it is shown in Table 6. It reveals that owners of TW were not aware about desirable use of ground water. They were lifting more quantity of water as per the requirement of summer paddy leading to poor water use efficiency under TW up to 5 HP SMP, TW above 5 HP SMP and TW + T sources of irrigation, whereas, well (W) and TW + R irrigation sources were unable to provide sufficient irrigation to the crop causing poor water use efficiency.

Policy Implications:

Empirical findings of the study suggested that summer paddy should be replaced with low water requirement crops from the pulse and oilseed groups' viz., green gram and groundnut to check the exploitation of ground water through TW irrigation sources. The nominal electricity charges are being charged from the owners of TW were the main reason for over utilization under TW irrigation sources. So, it is being suggested to the state electricity board

Table 6. Optimum use of minor irrigation source for crops grown in summer.

Minor Irrigation Source	Paddy	Groundnut	Green Gram
TW upto 5 HP SMP	0.38 (178.20)***	0.26(60.70)**	0.27(29.50)**
TW above 5 HP SMP	0.46(186.20)***	0.32(55.38)*	-
Well	0.43(119.40)*	0.38(59.59)**	0.29(32.44)**
Reservoir	0.54(155.13)**	0.35(52.52)*	0.26(22.80)*
TW + R	0.51(144.26)*	0.31(46.58)*	0.23(26.87)*
TW + T	0.36(175.13)***	0.29(61.24)**	0.30(27.50)**
O + T	-	0.027(56.25)**	-
Optimum Requirement	152-160	57-63	28-32

Note: *, Denotes the under utilization of irrigation water.
**, Denotes the optimum utilization of irrigation water.
***, Denotes the over utilization of irrigation water.

that electricity charges should be fixed on rational manner to control exploitation of ground water. Mustard is more remunerative crop in rabi season as compared to other crops therefore; it has been suggested to extension personnel to motivate the farmers for growing mustard in more acreage in place of other rabi crops like wheat. Government of Chhattisgarh state is giving the subsidy to marginal and small farmers for digging the tube-well, open well and dabhri under the programmes of Amrit Dhara Sichai Yojna, Rajeev Gandhi Jal Grahan Pariyoja, Jawahar Gramin Rojgar Yojna etc. It is therefore, suggested that minimum subsidy should be given to the farmers in case of success of bore but in case of failure the bore maximum subsidy should be provided to farmers. State Government does not have concrete plan for strengthening the minor irrigation sources so; it is a necessity to frame out optimum water use plan particular to ground water use.

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EFFECT OF INTEGRATED PLANT NUTRIENT SYSTEM ON PRODUCTIVITY AND PROFITABILITY OF PEA-SUMMER SQUASH CROPPING SYSTEM UNDER HIGH HILL COLD DESERT CONDITIONS

A.D. BINDRA, MAN SINGH, D.R. CHAUDHARY, HARBANS LAL AND Y.P. DUBEY

Directorate of Extension Education, CSKHPKV, Palampur-176062

ABSTRACT

A field experiment was conducted during 2006 and 2007 to evaluate the effect of organic sources of plant nutrients viz. FYM (Farmyard manure), *Rhizobium* (P-HP-3 strain), Phosphate solubilizing bacteria (PSB), FYM+*Rhizobium* and FYM+PSB along with chemical fertilizers in pea-summer squash cropping system. Application of FYM @ 2.5t/ha+*Rhizobium* resulted in significantly superior yield contributing characters of pea as well as summer squash crop. Hence, productivity of pea was highest in this treatment giving 131.6 q/ha of green pod yield. Residual effect on summer squash with FYM @ 2.5t/ha+*Rhizobium* when applied to pea produced 142.9 q/ha summer squash crop which consequently resulted in significantly higher pea equivalent yield (PEY) of 203 q/ha and system productivity of 1.11 q/ha/day. This effect was manifested in getting higher gross and net returns of the system (Rs. 246085 and 180350/ha, respectively). Application of 150% NPK through chemical fertilizers in pea and no application of fertilizers to summer squash resulted in significantly higher green pod yield of pea (141.0 q/ha) and summer squash 167.2 q/ha and higher PEY of 224.6 q/ha giving net profit of Rs. 205198/ha in the system.

Keywords: Pea, summer squash, FYM, *Rhizobium*, Phosphate solubilizing bacteria, chemical fertilizers

The cold desert (dry temperate) zones of Himachal Pradesh come under the trans-Himalayan zone, which lies in rain shadow of the main Himalayan range and is usually described as high altitude cold desert (snowbound). These areas remain covered with snow for about six months during winters i.e. October to March and remain cut off from rest of the world. Hence crops can be grown only in summer season i.e. April to September. Farmers get only one growing season and monocropping system is followed in these areas. Peculiar climate of this zone enables farmers to grow all *kharif* and *rabi* season crops simultaneously in the same season same fields. Crop intensification is possible either through intercropping or crop sequences in the short period of six months. The agro climatic conditions are most congenial for the production of disease free commercial high value off-season vegetable cash crops. Being single seasoned areas, farmers have to depend upon the integrated farming systems to harness the natural resource managements. Pea is the main commercial off-season vegetable crop. In some places farmers adopt pea-pea, pea-buckwheat or pea-sarson crop sequences. Variety 'Palam priya' of pea is performing very well in the valley (Akshilesh *et al.* 2007). However, with continuous growing of pea as monocropping some diseases may appear resulting in low productivity. As in the valley the only source of other fresh vegetables is lower parts of Himachal Pradesh and Punjab. There is immense demand in the valley itself and also in lower parts of H.P. being off-season vegetables and lack of package of practices of growing pea using organic sources in these cold desert areas of H.P., the present study was conducted under ICAR adhoc project to evaluate different sources of plant nutrients along with chemical fertilizers on pea-summer squash (summer squash - a new introduction) cropping system.

MATERIALS AND METHODS

A field experiment was conducted under the ICAR, ad-hoc project "Sustainable integrated crop and livestock management systems for snowbound zones of Himalayas" at CSK Himachal Pradesh Krishi Vishvavidyalaya, Highland Agricultural Research and Extension Centre, Kukumseri (Lahaul & Spiti) during 2006 and 2007. In the present experiment fifteen treatments combinations of five organic sources of plant nutrients *viz*. FYM @ 5 t/ha (Oven dry weight basis), *Rhizobium* (Indigenous strain from Lahaul and Spiti (Jhalma) P-HP-3) (@200g/10 kg seed), Phosphate Solubilizing Bacteria(PSB) (Indigenous strain from Kangra) (@200g/10 kg seed), FYM @ 2.5 t/ha + *Rhizobium* and FYM @ 2.5 t/ha + PSB and three fertility levels *viz*. 50, 100 and 150 per cent of the recommended (20:60:30 kg/ha) NPK were studied on pea crop and their residual effect on summer squash crop. Half dose of nitrogen and full doses of phosphorus and potassium were used at sowing time of pea and remaining half dose of nitrogen was applied after hoeing (40-50 DAS). The experiment was laid out in Split-plot design with three replications. In Pea (*Pisum sativum* L.) – Summer squash (*Cucurbita pepo* L.) crop sequence, pea (var. Palam Priya) was sown on May 4 and May 11 during 2006 and 2007 with 30 X 5 cm spacing and Summer Squash (var. Australian green) was transplanted on July 26 and August 9 during 2006 and 2007 respectively using 90 X 60 cm^2 spacing. The nursery of summer squash was raised in poly tubes under the poly house conditions. The plot size was 3.0 X 2.7 = 8.1 m^2 during both the years of study. For weed management in pea, pendimethalin @ 1.2 kg a.i. /ha was used as pre emergence herbicide and one hoeing was done 40-50 days after sowing. Irrigation was done as and when required by sprinkler irrigation system using the glacier gravity water. Field experiment was conducted at Highland Agricultural Research and Extension Centre, Kukumseri (2772 m amsl), Lahaul and Spiti during *kharif* seasons of 2006 and 2007. The soil was sandy loam in texture and neutral in reaction (pH 6.9). The initial soil contained 2.3% organic carbon, available nitrogen 248 kg/ha, phosphorus 46.3 kg/ha and potassium 171 kg/ha, respectively. Plant height (cm) was recorded before first picking. Number of pods/plant, number of grains/pod and pea shelling percentage were recorded at the time of picking. The following formula was used for the calculation of pea shelling percentage.

$$\text{Shelling percentage} = \frac{\text{Weight of grain}}{\text{Total weight of pod}} \times 100$$

Number of leaves/plant, number of fruits/plant, fruit weight (g), fruit dia. (cm^2) were recorded at the time of picking. Following formulae were used for calculating various parameters.

$$\text{Yield (q/ha)} = \frac{\text{Plot yield (q)}}{\text{Area under plot (m}^2\text{)}} \times 10000\ \text{m}^2$$

$$\text{Pea Equivalent Yield (q/ha.)} = \frac{\text{Sale rate of Summer Squash (Rs.)}}{\text{Sale rate of Pea (Rs.)}} \times \text{Yield of Summer Squash (q/ha)}$$

$$\text{Productivity (q/ha/day)} = \frac{\text{Yield (q/ha)}}{\text{No. of days taken by crop in half year (182.5 days)}}$$

Gross return (Rs.) was calculated on the basis of sale rate of crop. Total cost was calculated at the purchase sources. Net return (Rs.) per ha was worked out on the basis of following formula:

Net returns (Rs./ha) = Gross Return (Rs/ha) – Total Cost (Rs./ha)

$$\text{Economic Efficicency (Rs./ha/day)} = \frac{\text{Net returns (Rs./ha)}}{\text{No. of days taken by crop in half year (182.5 days)}}$$

$$\text{Benefit: Cost Ratio} = \frac{\text{Gross Returns (Rs./ha)}}{\text{Total cost (Rs./ha)}}$$

Method used for seed inoculation: Ten percent gur solution was prepared, which served as a sticker for *Rhizobium* and PSB cells to seeds. Then *Rhizobium* and PSB cultures (@200g /10 kg seed) were added to sticker solution and mixed thoroughly. This culture slurry was poured on seeds and again mixed thoroughly. Treated seeds were spread uniformly for drying on a gunny bag in shaded place. Now these inoculated seeds were ready for sowing.

Results and Discussion

Yield attributes of pea

Application of FYM @ 2.5 t/ha + *Rhizobium* resulted in significantly more number of pods per plant, number of grains per pod and higher shelling percentage of pea. In case of plant height, application of FYM @ 5 t/ha produced significantly taller plants than all other treatments. Whereas, FYM @ 2.5 t/ha + *Rhizobium* and FYM @ 2.5t/ ha+PSB remaining at par with each other followed it (Table 1).

Effect of NPK levels on yield attributes of pea in table 1 showed that the entire yield attributes were significantly affected by applying increased doses of NPK beyond recommended dose. Application of 150% NPK was followed by 100% NPK. Significantly lower values of all the yield attributes were recorded with the application of 50% NPK doses. The increase to the range of 5.5 to 8.2% was observed in the yield attributes with

Table 1. Effect of organic/bio-fertilizers and NPK levels on yield attributes of pea in pea-summer squash cropping system. (Pooled over 2006 and 2007)

Treatment	Plant ht. (cm)	No. of pods/plant	No. of grains/pod	Shelling (%)
Organic/bio-fertilizers				
FYM @ 5 t/ha	69.8	11.1	7.1	56.4
Rhizobium	66.3	11.0	7.3	57.9
PSB	66.0	10.1	6.6	54.4
FYM @ 2.5t/ha+*Rhizobium*	68.2	11.7	7.6	59.1
FYM @ 2.5 t/ha + PSB	68.1	10.9	7.0	55.6
CD (P=0.05)	0.65	0.13	0.11	0.52
NPK-Levels				
50%	61.0	9.5	6.5	51.7
100%	69.1	11.3	7.2	56.7
150%	72.9	12.0	7.6	61.7
CD (P=0.05)	0.60	0.17	0.09	0.55

the application of 150% over 100% NPK. Bindra and Thakur (2005) and Rana *et al.* (2006) also observed similar findings in pea and crop sequences with pea.

Yield attributes of summer squash

Yield contributing characters of summer squash were influenced by the residual effect of treatments imposed on pea crop. FYM @ 2.5 t/ha + *Rhizobium* applied to pea crop significantly increased the height of summer squash plants bearing more number of leaves per plant , more number of fruits per plant, more fruit diameter and more fruit weight (Table 2). However, application of *Rhizobium* alone to pea and its residual effect on summer squash also remained at par with this treatment in case of number of fruits /plant. FYM @ 5 t/ha to pea remained at par with these two treatments in case of leaf diameter and number of fruits/plant.

It was observed that 150% NPK levels when applied to pea crop resulted in more residual effects than 100% and 50% NPK doses. All the yield attributes of summer squash were significantly influenced with 150% NPK (table 2). Plants were significantly taller having higher number of leaves per plant with larger leaf diameter, more number of fruits per plants, more fruit diameter and fruit weight with 150% NPK to pea as compared to other levels of NPK under study. The increase in all the yield attributes with 150% NPK was in the range from 8.6 to 33.3 % over 100% NPK application.

Productivity of pea-summer squash cropping system

It was observed that pea green pod yield was significantly highest in the treatment receiving FYM @ 2.5 t/ha + *Rhizobium* (131.6q/ha) than all other treatments of organics and bio-fertilizers. This treatment was followed by FYM @ 5 t/ha (128.4 q/ha). Whereas, *Rhizobium* alone and FYM @ 2.5 t/ha + PSB treatments remained statistically at par with each other but resulted in lower green pea yields (Table 3 & Fig.1). Rana *et al.* (2006) studied the positive response of *Rhizobium* strains in the soils of these areas, resulting in higher crop

Table 2. Residual effect of organic/bio-fertilizers and NPK levels on yield attributes of summer squash in pea-summer squash cropping system. (Pooled over 2006 and 2007)

Treatment	Plant ht. (cm)	No. of leaves/ plant	Leaf dia. (cm)	No. of fruits/ plant	Fruit dia. (cm)	Fruit wt.(g)
Organic/bio-fertilizers						
FYM @ 5 t/ha	16.7	17.7	315.4	1.9	290.9	868.9
Rhizobium	17.2	18.6	298.4	2.1	275.0	840.4
PSB	15.4	16.7	271.8	1.6	262.5	754.6
FYM @ 2.5t/ha+ *Rhizobium*	18.4	21.2	306.7	2.1	298.1	936.3
FYM @ 2.5 t/ha + PSB	17.3	17.4	282.7	1.7	280.1	834.9
CD (P=0.05)	0.32	0.29	7.35	0.20	4.49	20.28
NPK-Levels						
50%	14.2	16.0	233.2	1.5	197.7	619.5
100%	17.3	18.6	314.9	1.8	308.7	899.4
150%	19.5	20.2	336.8	2.4	337.6	1022.2
CD (P=0.05)	0.31	0.36	6.81	0.11	4.76	14.53

Table 3. Effect of organic/bio-fertilizers and NPK levels on productivity of pea - summer squash cropping system. (Pooled over 2006 and 2007)

Treatment	Yield (q/ha)		Pea eqiv. yield (q/ha)	System Productivity (q/ha/day)
	Pea	Summer squash		
Organic/bio-fertilizers				
FYM @ 5 t/ha	128.4	127.6	192.2	1.05
Rhizobium	120.4	124.8	182.8	1.00
PSB	115.3	114.6	172.6	0.95
FYM @ 2.5t/ha+*Rhizobium*	131.6	142.9	203.0	1.11
FYM @ 2.5 t/ha + PSB	121.7	127.6	185.5	1.02
CD (P=0.05)	2.20	2.97	3.13	0.02
NPK-Levels				
50%	94.4	78.0	133.4	0.73
100%	135.0	137.4	203.7	1.12
150%	141.0	167.2	224.6	1.23
CD (P=0.05)	2.34	3.46	2.92	0.02

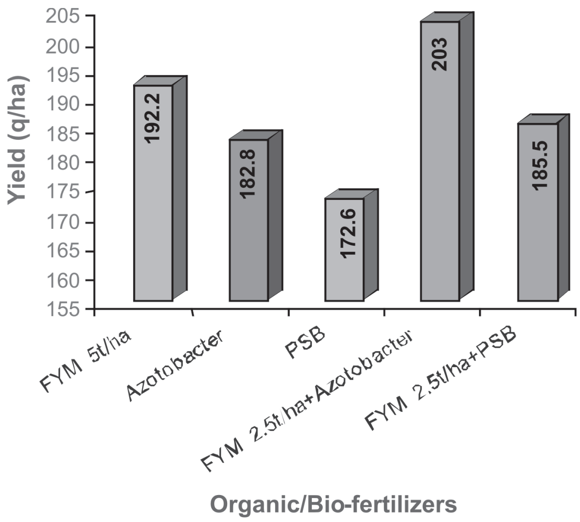

Fig. 1. Effect of Organic/Bio-fertilizers on Pea Equivalent Yield of Pea - Summer Squash Cropping System

yields than no inoculation. Similarly, Danielle *et al.* 2003 observed the encouraging effects of *Rhizobium* on pea crop. Decreasing FYM to 2.5t/ha but adding *Rhizobium* gave up to 2.5% more pea green pod yield compared to FYM @ 5t/ha alone. Similarly, compared to application of *Rhizobium* alone, the increase in pea green pod yields to the tune of 9.3% was observed with the addition of FYM @ 2.5t/ha along with *Rhizobium.* Whereas, when PSB was applied in place of *Rhizobium* along with FYM @ 2.5t/ha the green pod yields decreased to the tune of 8.13& on the pooled data basis of two years.

Residual effect of organic and bio-fertilizers was studied on succeeding summer squash crop in the same season. It was observed that application of FYM @ 2.5 t/ha + *Rhizobium* to pea crop resulted in significantly highest yield of summer squash (142.9 q/ha) followed by FYM @ 5 t/ha and FYM @ 2.5 t/ha + PSB. The later two treatments remained at par with each other. Residual effect with the application of *Rhizobium* along with FYM @ 2.5t/ha was more and its positive effect was manifested in getting significantly higher summer squash yields. Reducing FYM to 2.5t/ha from 5t/ha but adding *Rhizobium* resulted in 12.0% higher summer squash yields than application of only 5t/ha FYM. When compared with application of only *Rhizobim* to pea, it gave 14.5% less yields of summer squash than adding FYM @ 2.5t/ha to *Rhizobium*. Comparing residual effect of PSB instead of *Rhizobium* along with 2.5t/ha FYM, it again reduced summer squash yields to the tune of 12.0%. In case of pea equivalent yield the treatment receiving FYM @ 2.5 t/ha + *Rhizobium* resulted in significantly higher pea equivalent yield (203.0 q/ha) followed by FYM 5t/ha. Application of PSB alone resulted in lowest PEY. Similar trend of results were observed for system productivity as that obtained for pea equivalent yield.

Effect of NPK showed that application of 150% of recommended NPK to pea crop resulted in significantly highest green pod yield of pea (141.0 q/ha) followed by recommended dose of NPK. The yield advantage of 4.44% was observed over 100% NPK. Significantly lowest green pod yield was recorded with application of 50% NPK levels (Table 3 & Fig.2). Similarly, the residual affect of 150% NPK to pea resulted in significantly higher summer squash yields. The yield advantage of 21.69% was recorded while increased the NPK level by 50% over recommended. Further, pea equivalent yield and system productivity were also significantly higher with the application of 150% NPK doses to pea crop. With incremental doses of 50% over recommended increased the pea equivalent yields by 10.26% and system productivity by 9.82%, respectively.

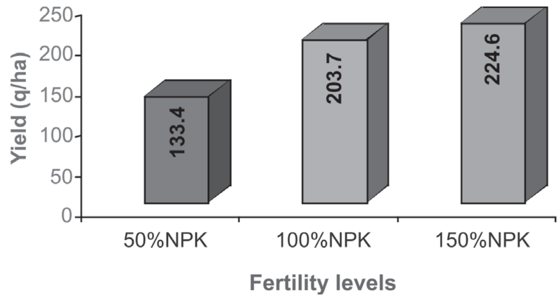

Fig. 2. Effect of Fertility levels on Pea Equivalent Yield of Pea - Summer Squash Cropping System

Profitability of pea - summer squash cropping system

Application of FYM @ 2.5 t/ha + *Rhizobium* to pea and residual effect on summer squash resulted in significantly higher gross returns (Rs.246085/ha), net returns (Rs.180350/ha), economic

Table 4.Effect of organic/bio-fertilizers and NPK levels on profitability of pea - summer squash cropping system. (Pooled over 2006 and 2007)

Treatment	Gross returns (Rs./ha)	Net returns (Rs./ha)	Economic efficiency (Rs./ha/day)	B:C ratio (Rs.)
Organic/bio-fertilizers				
FYM @ 5t/ha	233063	161153	883.0	3.24
Rhizobium	221695	158085	866.2	3.48
PSB	209283	145682	798.2	3.28
FYM @ 2.5t/ha+*Rhizobium*	246085	180350	988.2	3.74
FYM @ 2.5 t/ha + PSB	224908	159173	872.2	3.42
CD (P=0.05)	3794.79	3791.68	20.76	0.06
NPK-Levels				
50%	162000	96677	529.7	2.48
100%	246911	180791	990.6	3.74
150%	272109	205198	1124.3	4.07
CD (P=0.05)	3535.85	3541.13	19.39	0.05

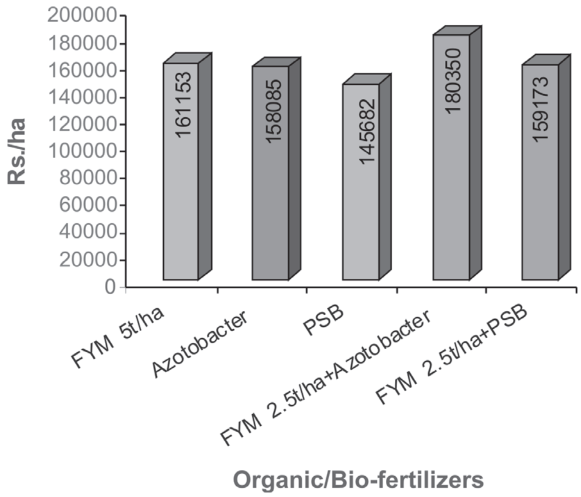

Fig. 3. Effect of Organic/Bio-fertilizers on net returns of Pea - Summer Squash Cropping System

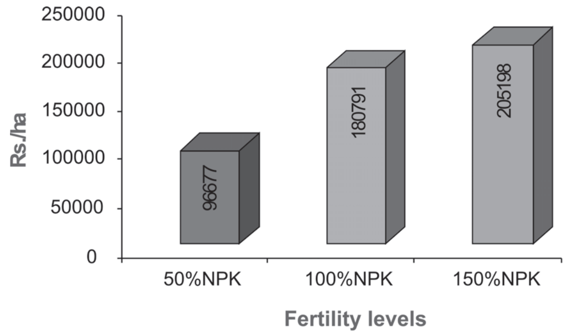

Fig. 4. Effect of Fertility levels on Net Returns of Pea - Summer Squash Cropping System

efficiency (Rs.988.2/ha/day) and B: C ratio Rs.3.74 for pea - summer squash cropping system. *Rhizobium* alone has followed this treatment except in case of B: C ratio (Table 4) (Fig. 3). However, application of only *Rhizobium* to pea significantly decreased net returns which were 14.08% less compared to addition of FYM @ 2.5t/ha along with *Rhizobium.* Similarly, net returns decreased by 11.91% with the application of only FYM @ 5t/ha compared to half quantity of FYM along with *Rhizobium.*

Observations recorded for economics parameters of pea-summer squash cropping system as influenced by levels of NPK showed (Table 4 & Fig. 4) that increasing doses of NPK from 100 to 150% significantly increased the gross and net returns, economic efficiency and B: C ratio. Significantly lowest values were recorded with the application of 50% NPK. Accordingly 13.5% higher net returns wee obtained with the increase of 50% NPK over recommended in pea-summer squash system as whole. Economic efficiency and B:C ratio of the system were also increased to the tune of 13.5 and 8.82% with 150% NPK as against recommended dose of NPK. Hence for obtaining higher returns of Pea-summer squash cropping system under high hill cold desert conditions application of FYM @ 2.5t/ha along with *Rhizobium* and 150% NKP were found to be quite effective.

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PERMANENT PLOT EXPERIMENT ON INTEGRATED NUTRIENT SUPPLY SYSTEM IN PEARL MILLET [*PENNISETUM GLAUCUM* (L.) R. BR. EMEND STUNTZ] – WHEAT (*TRITICUM AESTIVUM* L. EMEND. FLORI & PEOL) CROP SEQUENCE

A.S. Sheikh[1] and B.S. Patel[2]

A.I.C.R.P. ON C.S.R. Scheme, S. D. Agricultural University, Sadarkrushinagar-385 506

Abstract

A field experiment was conducted during 1986-87 to 1995-96 in North Gujarat Agro-climatic region to study the integrated nutrient management through organic and inorganic sources of fertilizer in pearl millet [*Pennisetum glaucum* (L.) R. Br. emend stuntz] – wheat (*Triticum aestivum* (L.) emend. Flori & Peol) crop sequence. The maximum pearl millet grain yield was obtained from 75 per cent recommended NPK dose through chemical fertilizer (80 - 40 - 00) + 25 per cent N through green organic manure (guar). While in *rabi*, the maximum wheat yield was obtained from 50 per cent recommended NPK dose through fertilizers along with 50 per cent N through crop residue (wheat cut straw) in *kharif* followed by 100 per cent recommended dose through chemical fertilizer in *rabi*. The total productivity in pearl millet wheat crop sequence was higher when the pearl millet crop received 50 per cent N through green manuring along with 50 per cent recommended NPK nutrients and 100 per cent recommended NPK nutrient to wheat crop. The total uptake of nutrients was higher when fertilizer was applied at 100 per cent recommended level. The nutrient status was built for nitrogen, phosphorus and organic carbon whereas potash content of soil was not much affected.

Key words : Pearl millet, wheat, integrated nutrient management, NPK, organic manure

Pearl millet [*Pennisetum glaucum* (L.)] – wheat [*Triticum aestivum* (L.)] is popular crop sequence in irrigated area in North Gujarat Agro-climatic Zone. The judicious and balanced fertilization through organic manures and inorganic fertilizers can maximize farm production per unit area. Organic manures and other renewable sources are helpful for the maintenance of soil fertility, but inorganic fertilizers will be one of the main instruments for increasing the pace of agricultural production. Thus, it is necessary to fid out their suitable combination with organic manures to get maximum yield of crops.

The present experiment was therefore, under taken to find out the long term effect of cereal based cropping sequence and manuring for getting higher crop production without impairing the soil health.

Materials and Methods

A field experiment was conducted during the year 1986-87 to 1995-96 of rainy (*Kharif*) and winter (*Rabi*) seasons at main Cropping Systems Research Centre, Gujarat Agricultural University, Sardarkrushinagar (Gujarat) on loamy sand soil with initial soil status of 191 kg N, 28 kg P_2O_5 and 216 kg K_2O/ha.

[1]Associate Professor, Veterinary College, SDAU, Sardarkrushinagar-385 506
[2]Chief Scientist, AICRP-CSR Scheme, SDAU, Sardarkrushinagar-385 506

The climate was arid. The long dry spell is common occurrence in the rainy season (Rainfall and rainy days is attached in Table 7).

The experiment was laid out in randomized block design in fixed plots having twelve treatments. The treatments consisted of applying different levels of inorganic fertilizers, either alone or in combination with organic manures at different proportions to rainy (*Kharif*) seasons pearl millet and only in organic fertilizers at different levels to the following winter (*Rabi*) season wheat (Table 1). The fertilizers levels were 100, 75 and 50 per cent of the recommended dose. The recommended fertilizers at 100 per cent level were applied @ 80 kg N, 40 kg P_2O_5 and 0 kg K_2O for rainy season pearl millet and 120 kg N, 60 kg P_20_5 and 0 kg K_2O for winter – season wheat. The inorganic fertilizers were supplied through urea and single super phosphate fully decomposed FYM and wheat cut straw were applied to

Table 1. Treatment details

Treatment	*Kharif*	*Rabi*
T_1	No fertilizerNo organic manure (Control)	No fertilizerNo organic manure (Control)
T_2	50% recommended NPK dose through fertilizers	50% recommended NPK dose through fertilizers
T_3	50% recommended NPK dose through fertilizers	100% recommended NPK dose through fertilizers
T_4	75% recommended NPK dose through fertilizers	75% recommended NPK dose through fertilizers
T_5	100% recommended NPK dose through fertilizers	100% recommended NPK dose through fertilizers
T_6	50% recommended NPK dose through fertilizers + 50 % N through FYM	100% recommended NPK dose through fertilizers
T_7	75% recommended NPK dose through fertilizers + 25 % N through FYM	75% recommended NPK dose through fertilizers
T_8	50% recommended NPK dose through fertilizers + 50 % N through wheat cut straw	100% recommended NPK dose fertilizers
T_9	75% recommended NPK dose through fertilizers + 25 % N through wheat cut straw	75% recommended NPK dose fertilizers
T_{10}	50% recommended NPK dose through fertilizers + 50 % N through green organic matter	100% recommended NPK dose through fertilizers
T_{11}	75% recommended NPK dose through fertilizers + 25 % N through green manure	75% recommended NPK dose through fertilizers
T_{12}	Farmer practices (40-00-00)	Farmer practices (80-00-00)

respective treatments and thoroughly mixed with soil by harrowing, whereas, green organic matter cluster bean (*Cyamopsis tetragonoloba*) was applied to respective treatments 30 days before sowing and was mixed in soil by harrowing. Full dose of P and half of N was applied at the sowing time and remaining half nitrogen was top dressed to both the crops at 30 days after sowing.

N content of grain and straw was determined by Kjeldhal's method (Jackson, 1973) and N uptake was calculated with the data of dry matter production.

Results and Discussion

The pooled data showed that grain yield of pearl millet increased significantly due to application of different organic and inorganic sources of fertilizers compared with control. The maximum pearl millet grain yield (1417 kg/ha) was obtained from 75 per cent recommended NPK dose through chemical fertilizer (80-40-00) plus 25 per cent N through green organic matter

Table 2. Pearl millet grain yield (kg/ha)

Treatment	YEAR								
	1986-87	1987-88	1988-89	1989-90	1990-91	1993-94	1995-96	Pooled	YxT
T_1	181	455	488	263	67	—	—	206	**
T_2	654	2037	1053	726	510	191	139	758	**
T_3	506	2188	1235	869	624	196	156	825	**
T_4	722	1924	1333	1061	559	247	170	858	**
T_5	940	2131	1538	1135	597	319	580	1034	**
T_6	712	2459	1225	1050	678	260	451	977	**
T_7	828	2847	1471	1170	623	326	479	1181	**
T_8	656	2211	1182	1038	636	214	403	906	**
T_9	700	2250	1220	1010	650	280	575	955	**
T_{10}	715	3030	1878	1962	736	351	486	1308	**
T_{11}	1160	3010	2270	1998	735	333	413	1417	**
T_{12}	822	1638	1323	1047	550	33	52	781	**
S.Em.± (kg/ha)	51	154	65	37	22	11	29	98	69.0
C.D. at 5 %	147	444	186	105	63	31	84	276	191
C.V.%	13.8	14.06	9.6	6.58	7.56	9.41	18.57	14.83	

1991-92, 1992-93 and 1994-95 failed

(Guar) but was at par with T_{10} (50% recommended NPK + 50 % N through green organic matter) and T_7 (75 % through recommended NPK chemical fertilizers + 25 % N through FYM) and superior to rest of all the treatments. This clearly indicates the beneficial role of organic matter. The same trend was also observed in most of the individual years data (Table 2).

The maximum wheat yield (1819 kg/ha) was obtained from T_8 (50% recommended NPK dose through fertilizer along with 50 % through crop residue in *kharif* followed by 100 % recommended dose through fertilizers in *rabi* (120-60-00). However, it was remained at par with T_3 (50 % recommended NPK fertilizer in *kharif* followed 100 % recommended NPK in *rabi*), T_5 (100 recommended NPK in *kharif* and *rabi*), T_6 (50 % recommended NPK through fertilizer + 50 % N through FYM in *kharif* a followed 100 % recommended dose in *rabi*), T_7 (75 % recommended NPK + 25 % N through FYM in *kharif* followed 75 % recommended NPK dose through fertilizer in *rabi*), T_{10} (50% recommended

Table 3. Wheat grain yield (kg/ha)

Treatment	YEAR										
	1986-87	**1987-88**	**1988-89**	**1989-90**	**1990-91**	**1993-94**	**1994-95**	**1995-96**	**Pooled**	**YxT**	**Total**
T_1	504	496	493	363	57	45	22	00	245	**	451
T_2	1618	1260	1568	691	658	630	695	344	933	**	1691
T_3	2684	2143	2401	757	1132	1410	1196	372	1512	**	2337
T_4	1817	1818	1929	720	872	1067	754	417	1174	**	2032
T_5	2066	2016	2131	650	898	1397	1809	1705	1584	**	2618
T_6	2387	2183	2228	818	1045	1428	2109	2130	1791	**	2768
T_7	2124	2166	2316	795	1023	1320	1815	2066	1703	**	2884
T_8	2464	1910	2323	965	1292	1542	2009	2046	1819	**	2725
T_9	1816	1603	2016	826	924	799	1664	1932	1448	**	2403
T_{10}	2373	1986	1660	528	1613	1255	1951	1982	1668	**	2976
T_{11}	2212	1798	1464	441	1477	1271	1877	1894	1554	**	2971
T_{12}	2041	1795	1689	608	832	1104	69	66	1025	**	1806
S.Em.± (kg/ha)	175	95	156	39	66	85	19	50	129	**	
C.D. at 5 %	505	274	449	112	197	246	52	144	362	278	
C.V.%	17.47	10.79	16.85	11.46	13.90	15.46	8.75	8.03	14.64		

NPK + 50 % N through green manuring in *kharif* followed 100 % recommended NPK dose through fertilizer in *rabi*), T_{11} (75 % recommended NPK + 25 % N through green manuring followed 75 % recommended NPK dose through fertilizer) in *rabi*. But the next treatment was T_6 (1791 kg/ha) (50 % recommended NPK + 50 % N through FYM in *kharif* followed 100 % recommended NPK in *rabi*). But, if we look into the average total grain yield of bajra and wheat crops substitution of 50 per cent N through the green manuring (guar) along with 50 per cent recommended NPK nutrients to *kharif* bajra and 100 per cent recommended NPK to wheat crop yielded (1976 kg/ha) which was closely followed by the treatment of 25 per cent N substitution through green manuring in conjunction with 75 per cent recommended N, P and K nutrients to *kharif* bajra and 75 per cent recommended N, P and K to the wheat crop. It clearly indicates that the application of green matter in combination with application in the form of inorganic fertilizers is superior to sole inorganic fertilization. Beneficial effect of green manuring (guar) and FYM application during *kharif* season on the succeeding wheat crop has also been reported by Chahal *et al.* (1984) (Table 3).

ECONOMICS

The results revealed that the highest net return of Rs.7290/ha was received from T_7 [application of 75 % recommended NPK dose through fertilizers + 25% N through FYM to pearl millet crop (80-40-00) NPK kg/ha] and 75 per cent recommended NPK dose through fertilizers to wheat crop *i.e.*, 90 kg N and 45 kg P_2O_5/ha (CBR 1.528) followed by net highest Rs.7257/ha from T_{11} (75 % recommended NPK + 25% N through green manuring to pearl millet and 75 % recommended NPK dose through fertilizers to wheat crop (90 kg N + 45 kg P_2O_5) (CBR 1.526) which are almost equal (Table 4).

It is evident that organic sources help to reduce 25 per cent nutrient requirement and also helpful for sustainable agriculture.

N, P and K uptake

The total uptake of NPK by plants was considerably higher when fertilizer applied at 100 per cent recommended level. It is evident that the higher uptake of the nutrients by the crops was contributed towards the increased grain yield which was not possible in the control (No fertilizer treatment) Table 5.

Soil fertility status

The data presented in Table 6, revealed that nutrient status was built for nitrogen, phosphorus and organic carbon whereas potash content of soil was not much affected (Table 6).

It could be inferred that in loamy sand soil, the pearl millet – wheat productivity could be improved with the application of fertilizers at 100 per cent recommended level of nutrients. It is clear that for maintenance of stable soil fertility in pearl millet – wheat cropping sequence a part of total nutrient should be applied through organic source like farm yard manure, green manure or wheat cut straw.

Table 4. Economics of crop sequence pearl millet and *rabi* wheat

Treatments	*Kharif* pearlmillet					*Rabi* wheat								
	Av. yield of grain (kg/ha)	Av. yield of straw (kg/ha)	Gross return (kg/ha)	Cost of culti-vation (kg/ha)	Net income (kg/ha)	Av. yield of grain (kg/ha)	Av. yield of straw (kg/ha)	Gross return (kg/ha)	Cost of culti-vation (kg/ha)	Net income (kg/ha)	Total net income (Rs./ha)	Gross profit *kharif* + *rabi* (Rs./ha)	Cost of culti-vation (Rs./ha)	Total CBR (Rs./ha)
T_1	206	765	1692	4197	-2505	245	508	1966	6300	-4334	6839	3658	10497	0.348
T_2	758	2233	5644	4981	663	933	1554	7308	7473	-165	498	12952	12454	1.040
T_3	825	2302	6015	4981	1034	1512	2205	11686	8646	3040	4074	17701	13627	1.299
T_4	958	2376	6237	5373	864	1174	1918	9177	8060	1117	1981	15414	13433	1.147
T_5	1034	2774	7427	5764	1663	1584	2299	12238	8646	3592	5255	19665	14410	1.365
T_6	977	2555	6952	5763	1189	1791	2387	13731	8646	5085	6274	20683	14409	1.435
T_7	1181	2725	8040	5737	2303	1703	2251	13047	8060	4987	7290	21087	13797	1.528
T_8	906	2563	6640	6519	121	1819	2510	13988	8646	5342	5463	20628	15165	1.360
T_9	955	2561	6859	6142	514	1448	2163	11218	8060	3158	3672	18077	14202	1.273
T_{10}	1308	3134	9020	6442	2358	1668	2364	12858	8646	212	6570	21870	15088	1.450
T_{11}	1417	3287	9664	6113	3351	1554	2176	11966	8060	3906	7257	21630	14173	1.526
T_{12}	781	1673	5188	4510	478	1025	1733	8042	7813	229	707	13230	12323	1.074

Table 5. Total nutrient uptake (kg/ha) under permanent plot experiment on integrated nutrient supply systems (Year : 1986-87 to 1995-96) Consequence : Bajra – Wheat

Nutrient/ Treatment		T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
1986-87	N	17.75	62.92	81.55	97.77	79.27	86.72	76.38	78.82	76.24	87.54	82.08	79.53
	P	6.26	19.49	28.87	21.85	25.06	26.70	22.76	28.08	22.10	28.70	27.00	23.20
	K	22.60	69.97	78.86	82.48	97.07	83.02	85.18	89.84	104.04	87.83	109.79	85.95
1987-88	N	13.17	50.56	52.90	57.06	62.04	61.42	63.65	56.17	63.47	80.66	73.81	42.69
	P	5.40	20.20	19.95	18.80	20.08	20.10	22.22	21.68	22.95	24.52	23.98	14.53
	K	37.70	115.90	104.64	102.45	118.20	120.23	122.66	138.89	145.47	146.56	128.29	78.44
1988-89	N	27.28	70.43	100.33	83.19	94.08	89.33	94.54	92.75	84.00	97.00	109.16	81.15
	P	10.54	27.96	41.12	34.75	37.18	36.13	40.95	39.58	34.60	36.81	39.97	30.79
	K	40.38	105.42	154.52	123.86	151.55	140.36	159.00	163.11	143.05	143.47	154.44	133.95
1989-90	N	21.76	47.59	58.89	61.75	59.09	65.19	71.28	62.65	59.49	82.39	76.92	56.34
	P	6.10	13.68	16.11	18.21	17.77	18.17	20.19	18.44	17.68	23.45	23.77	16.67
	K	37.80	78.73	86.39	95.00	87.28	95.96	98.66	81.36	88.93	130.52	125.03	88.75
1990-91	N	8.43	16.25	19.25	19.53	19.97	21.20	20.39	21.51	20.43	25.40	26.76	20.59
	P	2.14	6.72	7.73	7.85	8.41	14.64	8.31	9.13	8.14	10.15	10.02	8.23
	K	19.66	39.51	44.60	46.00	41.00	45.33	49.59	50.89	46.88	60.36	59.34	53.24
1991-92	N	5.92	25.03	38.00	29.82	27.70	32.97	30.96	40.42	28.88	44.00	42.51	30.91
	P	2.47	12.00	17.18	14.02	14.03	15.39	15.09	18.76	13.87	21.47	20.61	13.99
	K	17.25	45.94	55.82	56.07	49.07	48.64	48.73	58.17	44.32	55.78	57.85	53.48
1992-93							........FAILED........						
1993-94	N	4.37	39.55	59.21	50.25	63.97	57.56	58.63	68.46	48.46	62.02	59.64	33.64
	P	1.76	16.04	27.83	22.68	28.76	26.25	25.68	30.15	21.21	27.64	27.30	15.65
	K	8.20	61.10	73.08	73.00	85.44	76.17	87.84	88.48	74.33	96.21	82.83	35.79
1994-95	N	1.57	21.19	30.31	19.00	40.75	48.77	41.67	48.92	37.15	52.16	45.74	4.93
	P	0.35	4.46	6.07	3.90	8.96	11.14	11.45	10.14	8.60	10.16	11.00	0.69
	K	2.97	15.66	25.08	16.04	33.93	41.70	35.71	37.54	32.82	28.60	39.63	4.16
1995-96	N	3.25	31.52	40.67	40.92	86.49	86.91	85.93	75.50	73.54	80.17	73.30	7.81
	P	0.81	7.08	10.91	11.55	26.05	22.86	17.76	18.19	15.81	21.03	17.99	1.52
	K	7.13	57.98	83.79	74.67	121.79	107.49	96.17	100.38	90.15	114.11	97.26	16.72

Table 6. Soil fertility status (kg/ha) after *rabi* crops under permanent plots experiment on integrated nutrient supply system (Year : 1986-87 to 1995-96) Crop sequence : Bajra – Wheat

Available Nutrients (kg/ha)		Treatments											
		T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
1990-91	N	142.5	147.5	152.5	149.5	152.5	146.0	142.5	144.5	152.5	146.0	147.5	152.5
	P	18.5	14.5	12.5	15.5	14.5	13.5	13.5	11.0	15.0	16.5	17.5	15.5
	K	180.5	175.5	165.5	165.5	150.6	170.0	170.5	180.5	165.5	165.5	170.5	170.5
O.C.(%)	0.12	0.14	0.14	0.13	0.25	0.15	0.10	0.21	0.23	0.21	0.17	0.14	
1991-92	N	152.5	149.5	157.5	152.5	146.0	152.5	149.5	152.5	146.0	157.5	152.5	146.0
	P	14.0	15.5	17.5	15.5	18.5	14.5	17.5	18.5	13.5	14.5	15.5	15.0
	K	176.0	180.0	184.0	180.0	188.0	180.0	180.0	188.0	180.0	160.0	172.0	177.0
O.C.(%)	0.21	0.23	0.20	0.22	0.22	0.23	0.25	0.21	0.22	0.23	0.25	0.23	
1993-94	N	158.0	158.0	160.0	163.0	160.0	159.0	158.0	158.0	158.0	158.0	157.0	159.0
	P	22.0	20.0	19.0	29.0	20.0	21.0	21.0	21.0	21.0	19.0	21.0	22.0
	K	193.0	199.0	202.0	207.0	199.0	204.0	209.0	199.0	204.0	207.0	207.0	199.0
O.C.(%)	0.23	0.26	0.23	0.24	0.21	0.24	0.25	0.26	0.27	0.25	0.20	0.22	

Table 7. Statement showing year and monthwise actual rainfall rainy days

Year		Month											
		June	July	August	September	October	November	December	January	February	March	April	May
1986-87	Actual rainfall	28.5	80.9	74.5	-	-	-	-	-	-	-	-	-
	Rainy days	4	5	4	-	-	-	-	-	-	-	-	-
1987-88	Actual rainfall	79.56	25.89	34.11	0.67	-	5.22	-	-	-	-	-	-
	Rainy days	4.2	1.6	2.3	0.1	-	0.4	-	-	-	-	-	-
1988-89	Actual rainfall	9.7	264.6	70.4	105.2	-	-	-	6.7	-	-	-	-
	Rainy days	1	15	6	3	-	-	-	1	-	-	-	-
1989-90	Actual rainfall	98.2	112.6	429.4	124.2	7.0	4.4	-	-	10.2	-	-	1.6
	Rainy days	3	4	9	4	1	4	-	-	2	-	-	2
1990-91	Actual rainfall	6.2	310.6	450.6	76.0	40.2	-	-	-	-	-	-	-
	Rainy days	3	9	18	5	2	-	-	-	-	-	-	-
1991-92	Actual rainfall	16.6	213.0	20.0	37.8	-	-	-	6.5	-	-	-	-
	Rainy days	1	14	3	2	-	-	-	2	-	-	-	-
1992-93	Actual rainfall	8.0	699.9	233.3	57.0	-	8.0	-	-	11.0	-	-	-
	Rainy days	1	18	7	6	-	1	-	-	2	-	-	-
1993-94	Actual rainfall	74.5	2.0	39.7	1.0	-	19.2	-	0.5	-	-	-	-
	Rainy days	4	11	2	4	-	1	-	-	-	-	-	-
1994-95	Actual rainfall	146.1	651.8	536.4	289.8	-	-	-	2.0	-	5.3	-	-
	Rainy days	6	13	21	9	-	-	-	1	-	1	-	-
1995-96	Actual rainfall	-	287.4	153.9	31.4	32.1	-	2.8	6.3	-	-	-	-
	Rainy days	-	13	7	8	2	-	1	1	-	-	-	-

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EFFECT OF YIELD, YIELD ATTRIBUTES AND ECONOMICS OF MAIZE VEGETABLE PEA-WHEAT CROP ROTATION IN CENTRAL PART OF U.P.

A.K. Yadav, S.K. Chauhan, and S.K. Shiroti

R.B.S. College, Bichpuri, Agra-283 105.

Abstract

A field study was conducted during the winter (*Rabi*), *Kharif* seasons of 2004-05 and 2005-06 at C.S.A. University of Agriculture and Technology, Kanpur (U.P.) to evaluate date of sowing (30 September, 10 October and 20 October) and N levels (N_0, N_{20},N_{40},N_{60} and N_{80} Kg ha^{-1}) in the vegetable Pea only. The vegetable Pea – wheat – Maize crop rotation repeated continuously on the fixed plot for the two years. The N levels were applied in vegetable pea and second (wheat) and third (Maize) crop were grown on residual fertility. Based on the two years average data for yield attributing characteristics i.e. No of pod, pod length, width of pod, pod weight per plant etc. were significant and maximum in last date of sowing (20th October). The N levels of vegetable pea attributes significantly higher in N_{80} and more than the other levels N_{60},N_{40},N_{20} and N_0. The green pod weight of vegetable pea was significantly maximum in last date of sowing during individual years and pooling. The higher pod yield 54.3q ha^{-1} which was found, 4.3 and 8% higher than the pod yield obtained in 10 October and 30 September respectively. At N levels of vegetable pea the significantly higher yield recorded to be 54.8 q ha^{-1} which was calculated to be 0.8, 2.7, 6.5 and 1.5% higher than N_{60},N_{40}, N_{20} and N_0 levels. The residual effect of pea treatment on wheat crop in yield attributing characters was significantly maximum in first date of sowing over second and last date of sowing. The N levels in the attributes were significantly higher in N_{80} than other levels. The yield of wheat crop was maximum in first date of sowing 36.6q ha^{-1} which was found 3.0 and 6.0% higher second and last date of sowing. The residually of N_{80} being at par with N_{60} and N_{40} levels producing significantly higher yield of wheat than N_{20} and N_0 levels. The third maize seed yield did not significantly result in all attributes and grain yield. The net profit of vegetable pea was maximum in first date of sowing Rs.29,634 ha^{-1} and wheat crop may be highly profitable in first date of sowing Rs.11,181 ha^{-1} and maize crop Rs.6,394 ha^{-1} in first date of sowing. The net profit in N levels use was higher and residual effect in wheat and maize crop were maximum net profit in N_{80} Rs.24,726 ha^{-1} in vegetable pea, Rs.11,305 ha^{-1} in wheat N_{80} and maize crop net profit did not significant by residual effect of any treatment on pooled basis.

Key words: Vegetable pea, wheat, Maize and crop rotation etc

The high intensity cropping sequences in Agricultural developed areas may play an important role. The sequences involving two or more food grain crops with inclusion of legumes are of paramount importance, as these will maintain the soil. The input requirements of such sequence well go down, as the leguminous crops require lesser amount of fertilizer and irrigation. The succeeding wheat comparable to that applied to wheat in sequence more efficiently utilized phosphorus applied to soybean. Maize-vegetable-wheat sequence is more feasible and acceptable to farmers in the wheat belt of north India, especially in area with assured irrigation. The inclusion of legumes and straw incorporation in a cropping system improves the productively of soil and the yield of subsequent non-legume owing to provision of N and other growth promoting factors such as increased nutrial availability, improved soil structure and reduced daises incidence.

Fertilizer nutrients supply is another important factor of production. Necessity of phosphorus for a legume crop like pea needs no emphasis while status of nitrogen use has become controversial particularly in vegetable pea varieties. Since a crop utilizes a limited part of applied nutrient. The present investigation was earned out to study.

Materials and Methods

A fixed plot field experiment was carried out during 2004-05 and 2005-06 at students instructional farm of the C.S.A. University of Agriculture and Technology, Kanpur on sandy loam soils which was slightly saline (pH 7.8), low in organic carbon (0.45%) and available N (225 Kg ha^{-1}) and medium in available P (15.1 Kg ha^{-1}), K (176 kg ha^{-1}). The fixed plot experiment was laid out in three times replicated split plot design except for the first crop of vegetable. The first crop "Arkel" for vegetable Pea was grown during *rabi* season of 2004-05 in forth week of September to last week of December, received three treatments in date of sowing viz. September 30, October 10 and October 20 and five levels of nitrogen i.e. control (No), 20,40,60 and 80 Kg ha^{-1} to succeeding (K-7903 Halna) wheat which was sown in the third week of December to first week of January and harvested in to last week of April. After the harvest of wheat (*Azad uttam*) Maize was grown on residual fertility during *Kharif* season. This crop rotation of vegetable Pea – wheat – Maize was grown continuously for two years on the same site. The vegetable pea received all treatments like date of sowing and nitrogen level only but wheat and maize crop as residual effect of the vegetable pea fertilization in both the years. The phosphorus and potassium were applied through single super phosphate and murate of potash in the sowing time respectively. The nitrogen applied through urea was at per treatments. Other management practices were adopted as per recommendations and need of the crop. Seed/grain yield of component crops and important yield attributes were worked out based on the net plot yield and randomly selected four plants sample. Net production value in the system i.e. net profit/unit of cost of cultivation was worked out to asses the residual effect of treatments. Soil samples were taken from 0-22.5 cm soil layer at the beginning and end of experiment of find out initial status of experimental site soil and changes in available N,P and K in the soil after the experimental period. Soil samples drawn at the beginning of the experiments were analyzed for organic carbon, pH and available NPK by following standard procedure. The data was analyzed for analysis of variance by following standard statistical procedure. The rainfall receiving the crop rotation time, no rain received at vegetable pea, 35.5 and 39.5 mm wheat and no rain received at maize period in 2004-05 and 2005-06 respectively.

Results and Discussion

Date of sowing on yield and yield attributies

Yield attributes of vegetable pea, viz. No. of pods/plant, pod length (cm), pod breath (cm), pod weight (gm), seed weight (gm/plat), No. of seed/pod and shelling (%) recorded significant variation due to date of sowing September 30, October 10 and October 20 in pooled analysis in the two year of experimentation (Table-1). Number of pods increased significantly with each delay in sowing and maximized (15.7) under last sowing which produced 6.2 and 23.5% higher number of pods than

Table 1. Yield attributing characters of vegetable pea as affected by different treatments (Pooled Data)

Treatment	No. of pods/ plant	Pod length (cm)	Pod breath (cm)	Pod weight (g/pod)	Seed weight (g/pod)	No. of Seed/ Pod	Shelling (%)
Date of Sowing							
30th Sept.	12.7	8.1	1.2	12.1	5.5	4.3	42.5
10th Oct.	14.8	8.8	1.3	13.1	6.4	4.7	43.4
20th Oct.	15.7	9.3	1.3	14.1	7.6	5.0	44.6
CD at 5%	0.4	0.3	0.04	0.4	0.4	0.2	0.7
N levels (Kg ha^{-1})							
N_0	11.4	7.5	1.1	8.8	3.8	3.5	39.1
N_{20}	13.6	8.4	1.2	11.9	8.1	4.3	42.8
N_{40}	14.6	9.0	1.3	13.9	6.9	4.8	43.9
N_{60}	15.8	9.3	1.3	15.2	7.1	5.2	45.6
N_{80}	16.6	9.5	1.3	15.8	8.5	5.6	46.2
CD at 5%	0.7	0.5	0.08	0.9	0.8	0.4	1.5

under 10 October and 30 September respectively on pooled basis. In pooled results in pod length 20 on sowing produced maximum pod length of 9.3 cm which was found 5.8 and 15-2% more than 20 October and 30 September. The pod breadth results became significant when 20th October sowing being at par with 10th October produced pods with more width than 30 September sowing but difference remained very nominal. The pod weight increase significantly with each delay in sowing and maximized at last sowing on 20th October with 14.1 g/plat weight on pooled basis which was 7.8 and 16.3%, more than pod weight of 10th October and 30th September, respectively. Pooled data show that 20th October sowing produced highest of 7.6 gm/plant seed which was 19.4 and 39.7% higher than the weight under 10th October and 30 September. In pooled results 20th October sowing contained maximum of 5.02 seeds/plant which was found 7.0 and 17.3% more over seeds with 10 October and 30th September, respectively. In case of shelling per cent 20th October sowing gave highest of 44.6% shelling which was found 1.15 and 2.10% unit more than shelling under 10th October and 30th September sowing dates. Similarly, Sharma (2002) observed greatest pod number/plants, pod length and seed/pod in 30th October sowing than earlier sown crop of "Arkel" pea on 15th October. Green pod yield increase significantly with each delay in sowing and this maximized under last sowing on 20th October, during both individual years and also in pooling. In pooled results 20th October sowing produced highest pod yield of 54.3q ha^{-1}, which was found or 4.3% and 8% higher than the pod yield obtained in 10th October and 30 September sowing respectively.

Hooda et al (1984), Sharma (2002) reported that yield attributes of pea were better in later sowing than earlier sowing.

N Levels in Yield attributes and Yield

The pooled results of No. of pods/ plant, N_{80} significantly maximum of 16.6

pods/plant and this number was computed to be 5.1, 13.6, 21.5 and 45.4% more than pods at N_{60}, N_{40}, N_{20} and N_0 levels. Pod length and breadth in pooled basis N_{80} level significantly produced maximum pod length 9.5 cm which was higher by the margins 2.7, 5.5, 13.0 and 27.6% over pod length at N_{60},N_{40},N_{20} and N_0 levels. The pooled data clearly indicated that significantly maximum pod weight/plant 15.8 gm in N_{80} levels which was found 3.8,13.9,33.3 and 80.2% more than pod weight recorded at N_{60},N_{40},N_{20} and N_0 levels. Seed weight per plant in pooled basis was significantly higher in N_{80} 8.57g/plant it was calculated to be 19.3, 22.0, 38.8 and 24.4% more than seed weight at N_{60}, N_{40}, N_{20} and N_0 levels, respectively. The seed/ pod N_{80} produced significantly maximum 5.67 seed/pod this number remained 8.2, 15.6, 29.5 and 60% more the seeds N_{60}, N_{40},N_{20} and N_0 in pooled basis. The shelling percent on mean basis over years maximum of 46.2% shelling was N_{80} levels which was found higher by 0.57,2.25,3.35 and 7.05% over shelling percent at N_{60},N_{40},N_{20} and N_0 respectively. Gangwar and Sharma (1988), Sharma and Choker (1989) reported like wise. Increasing levels of N increased pod yield up to highest level of N_{80}. The yield at this level of N remained at par with the yield at N_{60} level but significantly higher than all other lower levels of N during second year and pooling. In first year, yield at N_{40} level was also found at par with the yield at N_{80} level of N. In case of pooled data, N_{80} produced highest pod yield of 54.8 q ha^{-1} which was calculated to be 0.8%, 2.9%, 6.8% and 15% higher than the pod yield obtained at N_{60}, N_{40},N_{20} and N_0 levels of N respectively. Patidar and Mali (2002) and Singh et al (2002) reported same results. The interaction of the N and date of sowing was did not significant in both the years and pooled analysis in attributes and yield respectively (Tables-1&3.

Residual effect of Pea treatments on wheat crop

The pooled data of the yield attributing characters of wheat crop i.e. number of spike, grain/spike, grain weight/spike and 1000 gram weight (gm) were recorded and presented here (Table-2). The spy kill maximum 14.9 spiklet/spike and this number remained 7.5 and 12.0% higher than the spiklets outs offer pea showing 10th, 20th October. The number of grain per spike showed that first pea sowing produced maximum of 40.4 grain/spike and it was computed 9.0 and 16.8% more than grains under 10th and 20th October sowing. The pea sowing first 30th September maximum 2.38 gm grain/spike of wheat which was found to be 12.3 and 14.2% higher than

Table 2: Yield attributing characters of wheat as affected by different treatments (Pooled Data).

Treatment	No. of Spikelts	Grain/ Spike	Grain wt./ Spike (g)	1000 grain wt. (g)
Date of Sowing				
30th Sept.	14.91	40.40	3.38	35.74
10th Oct.	13.87	37.05	2.12	35.07
20th Oct.	13.31	34.60	2.08	34.18
CD at 5%	0.35	0.65	0.19	0.68
N levels (Kg ha^{-1})				
N_0	11.95	33.40	1.79	33.43
N_{20}	12.20	35.68	2.02	34.50
N_{40}	14.28	36.67	2.23	35.12
N_{60}	15.42	39.38	2.38	35.80
N_{80}	16.30	41.61	2.43	36.10
CD at 5%	0.84	1.42	0.22	1.43

grain weight under 10th and 20th October pea sowing. The test weight of wheat grain more 35.7 (g) was recorded in first sowing of pea which remained 1.9 and 4.6% higher than test weight recorded after second and third sowing. Samra *et al* (1989), who observed better grown and yield attributes of wheat in earlier sowings.

Grain yield of wheat was obtained significantly higher after pea sowing 30th September during first year and pooling while in second year, 10th October sowing remained at par with 30 September pea sowing (Table-3). Both later pea sowing produce grain yield of succeeding wheat at par with each other in pooled basis 30th September, pea sowing produced maximum grain yield (36.6 ha^{-1}) of wheat which was found 3.0% and 5.2% higher than the grain yield recorded after pea sowing 10th and 20th October respectively. These results are in accordance to the Singh and Dixit (1985).

The pooled results of residual N,N_{80} produced maximum of 16.3 Spike length for Spike which were 5.7, 14-1, 33.6 and 36.4% more than N_{60},N_{40}, N_{20} and N_0 levels. Number of grain/spike significantly higher in N_{80}, 41.6 and this Number was found 5.7, 13.5, 16.6 and 24.6% more over N_{60},N_{40}, N_{20} and N_0 levels. The grain weight/spike (g) was higher in N_{80} levels 2.43 (gm) which was 2.1, 9.3, 20.8 and 36.0% more than N_{60},N_{40}, N_{20} and N_0 levels. The test weight results in respect of N in pooled basis N_{80} levels more 36.1 (gm) which was found 0.8,2.8, 4.6 and 8% more than N_{60},N_{40},N_{20} and N_0 levels, respectively.

The grain yield of succeeding wheat crop increased numerically due to increase in residual N but margins of increase could not touch the levels of significance in individual years while in pooled analysis, differences become significant. The residual of N_{80} being at par with N_{60} and N_{40} levels produced significantly higher grain yield of wheat than N_0 and N_{20} levels. The interaction effect was not found significant in date of sowing and N levels. These results confirm the findings of Patidar and Mali (2002).

Table 3: Green pod yield of Pea and grain yield of wheat and maize (q ha^{-1}) under different treatments

Treatments	Pea			Wheat			Maize		
	2004-05	**2005-06**	**Polled**	**2004-05**	**2005-06**	**Polled**	**2004-05**	**2005-06**	**Polled**
Date of Sowing									
30th Sept.	51.0	49.6	50.3	37.3	35.9	36.6	32.2	32.3	32.3
10th Oct.	52.9	51.3	52.1	36.0	35.1	35.6	32.3	32.3	32.3
20th Oct.	52.9	53.7	54.3	35.0	34.1	34.8	31.8	32.2	32.0
CD at 5%	1.1	1.2	0.78	1.2	1.1	0.7	NS	NS	NS
N levels (Kg ha^{-1})									
N_0	48.3	46.8	47.6	34.3	33.9	34.1	31.9	32.4	32.1
N_{20}	52.4	50.2	51.3	35.7	34.7	35.2	32.2	32.7	32.2
N_{40}	54.1	52.3	53.2	36.2	35.3	35.8	32.3	32.3	32.3
N_{60}	54.9	53.7	54.3	37.0	36.0	36.5	32.1	32.1	32.1
N_{80}	55.0	54.5	54.8	37.3	36.3	36.8	32.2	32.5	32.3
CD at 5%	1.0	2.1	1.4	NS	NS	1.5	NS	NS	NS

Residual effect of pea treatment on Maize

Grain yield of Maize

The grain yield of maize was not influenced significantly by any treatment factors applied to pea crop. Results remained similar during both years experimentation and also in pooled analysis (Table-3).

Net profit for Pea – wheat – maize

The pooled data showed that 30th September sowing gave maximum of Rs.29,634 ha^{-1} as net profit and this value remained Rs.8173 ha^{-1} and Rs.14692 ha^{-1} more over Net profit received with 10th and 20th October, respectively. On the basis of pooled results first sowing earned more Rs.11,181 ha^{-1} Net profit which was found 9.3 and 17.5% more over Net profit in second and last pea sowing in wheat crop. The maize crop net profit in pooled basis found Rs.6,394 ha^{-1} first date g sowing. Dass et al.(2005) and Sharma (2002) in pea crop.

On the basis of pooled data N_{80} levels Rs.24,726 ha^{-1} net profit by was found to be higher 0.3, 4.2, 10.6 and 27% over net profit recorded N_{60},N_{40},N_{20} and N_0 respectively. In case of wheat crop net profit in pooled data was higher N_{80} in Rs.11,305 ha^{-1} which was found 1.7,7.9, 13.4 and 30.3% more than the net profit at N_{60},N_{40},N_{20} and N_0 levels respectively. The results clearly indicated that the maize crop net profit was not significantly by residual effect of treatment applied to pea-wheat system (Table-4). Azad et al (1992), Singh (1993), Singh (2000) in Pea crop and Sharma and Rajput (1997) in wheat crop gave the same results.

Table 4: Net profit (Rs ha^{-1}) from vegetable Pea, Wheat and Maize crop under different treatments. (Polled)

Treatments	Vegetable pea	Wheat	Maize
Date of Sowing			
30th Sept.	29,634	11,181	6,394
10th Oct.	21,461	10,230	6,388
20th Oct.	14,942	9,512	6,235
N levels (Kg ha^{-1})			
N_0	19,119	8,676	6,303
N_{20}	22,362	9,965	6,471
N_{40}	23,739	10,472	6,379
N_{60}	24,640	11,120	3,254
N_{80}	24,272	11,305	6,418

Green pod Rs.$D_1$1000, $D_2$750 and D_3 600q^{-1}, Wheat 640q^{-1} and Maize 550 q^{-1}.

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EVALUATION OF NUTRIENT MANAGEMENT OPTIONS FOR YIELD UPTAKE, INTERNAL NUTRIENT USE EFFICIENCY AND ECONOMICS IN MAIZE INTERCROPPED URDBEAN-WHEAT SYSTEM

VINOD KUMAR, T R RATHORE*, A.K.SHUKLA**, S.P.MAZUMDAR, G.C.SHARMA AND PREM SINGH

Project Directorate for Farming Systems Research, Modipuram, Meerut, Uttar Pradesh-250 110

ABSTRACT

In order to find out best IPNS option a field experiment was conducted during 2000-2001 and 2001-2002 at CRC, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttaranchal in maize + urd - wheat cropping system with nine nutrient management options in various combinations of organic, inorganic and bio-fertilizers. The objectives of the study were to (1) quantify the effects of IPNS (farmyard manure (FYM), bio-fertilizer application and straw incorporation in different combination with NPK) on yield, system productivity and profitability and (2) assess the potential effects of IPNS options on nutrient uptake and internal nutrient use efficiency. On the basis of two years pooled data, the treatment (10 t ha^{-1} FYM + Chemical fertilizer) performed better and recorded the highest system productivity, however, the component crop yield varied with treatment, e.g. maximum corn and wheat yield were recorded in T_3 while highest urdbean yield was noted in T_8. The application of wheat crop residues + 50% recommended dose of NPK gave the poorest yield. The total NPK uptake was more in wheat (249 kg ha^{-1}) than maize ((217 kg ha^{-1}) and urdbean (111 kg ha^{-1}). The internal nutrient use efficiency (INUE) also enhanced with inclusion of FYM or bio fertilizer in fertilization schedule.

Key words: IPNS, maize + urd – wheat, yield, INUE, system productivity, economics

Maize-wheat is the dominant cereal rotation followed in western Himalayan zone including states of Punjab, J & K, Himachal Pradesh, Haryana, Bihar, U.P. Uttaranchal and in some parts of Rajasthan. The total area under Maize-wheat system in our country is around 1.86 m ha. Being heavy feeder of nutrients maize-wheat system heavily removes the N, P, K per hectare besides large amounts of micronutrients from natural resources and sulphur resulting in heavy drain of nutrients from soil. The interactive advantages of combining organic and inorganic sources of nutrients in INM have proved superior to the use of its each component separately. At the same time soil nutrient resources alone or use of NPK will not be able to support the intensive cropping as mining of secondary and micronutrients from natural resources are becoming the limiting factor. Moreover, biological health of soil is deteriorating due to continuous application of NPK alone. One of the most important ways to improve fertilizer use efficiency is to develop fertilizer recommendations for cropping systems rather than for individual crops in isolation. Intercropping with leguminous crop could be another strategy to sustain soil health and system productivity (Singh, 2001). Inforth coming decades, a major issue would be to find the suitable agricultural systems to sustain and enhance soil productivity by appropriate application of plant nutrients. The low input sustainable agriculture and reduced chemical input concepts focus

*Ex-Professor, G.B. Pant University of Agriculture and Technology, Pantnagar
**Principal Scientist, CRRI, Cuttack

on the agricultural practices, such as crop residues incorporation, FYM, use of biofertilizers and inclusion of legumes in crop rotation. These practices will not only improve productivity but, will also maintain soil organic matter at an adequate level. Moreover, the productivity of cropping system depends on efficient utilization of residual and cumulative nutrients. Recommendations for nutrient management in individual crops of maize (Kumar *et al.*, 2003) are available but for system it is lacking. Thus, the present study was so designed that effect of different IPNS options were assessed along with introduction of legume as inter crop.

Materials and Methods

A field experiment was conducted in maize + urdbean -wheat system at Crop Research Centre of the G.B. Pant. University of Agriculture and Technology, Pantnagar, (Uttaranchal) situated at 29^0N latitude, 79.3^0E longitude and an altitude of 243.8 m above the mean sea level (MSL) during 2000-01 and 2001-02 in randomized block design with nine treatments viz; T_1 = recommended NPK (120:60:40) T_2 = soil test crop response , T_3 = 10 tones FYM ha^{-1} + rest through chemical fertilizers, T_4 = *Azotobacter* + 75% N and full dose of P&K through chemical fertilizers, T_5 = VAM (*Vesicular arbuscular mycorrhizae*) + 50 % P and full dose of N & K through chemical fertilizers, T6 = PSB (*Phosphorus solubilizing bacteria*) + 75% P and full dose of N & K through chemical fertilizers, T_7 = *Azotobacter* + VAM + PSB + 75% N, 25% P and 100% K through chemical fertilizers, T_8 = *Azotobacter* + VAM + PSB + 10 tones FYM and 33% N, no P and K through chemical fertilizers, T_9 = wheat crop residues + 50% recommended dose of NPK (Table 1) and three replications in Kharif. In succeeding wheat, the recommended NPK were use in all the treatments as common dose. The experimental site was loam (Mollisols), neutral in reaction, i.e. pH 7.01; normal EC, 0.278 dsm^{-1}, high organic carbon status (7.5 g C kg^{-1}), and medium in available soil nitrogen, phosphorus and potassium i.e. 220, 16.9 and 245 kg ha^{-1}, respectively. Maize cv Amar D 941 and urd cv PU-19 were sown each year in July using paired row technique (2:2) and harvested in October. Wheat cv U.P. 2425 was taken as succeeding crop sown in last week of November and harvested in third week of April. The manures and fertilizer were applied as per treatments and recommended practice of application. The maize equivalent yield and internal nutrient use efficiency (INUSE) were calculated using standard formulae.

Results and Discussion

Maize yield and attributes

Pooled data over two years revealed that most of the IPNS options, except T_6 and T_9 were found superior compared to application of inorganic fertilizer only. Among the IPNS options, application of 10 tones FYM ha^{-1} + recommended NPK through chemical fertilizers recorded significantly higher maize grain yield followed by T_8 which was comparable with T_4 (Table 1).

The enhancement in yield was ascribed to more number of cobs per unit area, greater number of grains per cob, better shelling percentage and higher 1000-grain weight due to integrated use of FYM + chemical fertilizer (T_3).The combined use of biofertilizers (VAM + PSB + Azotobactor) along with 10t FYM + 33% recommended N without P and K application also resulted significantly higher grain yield over other remaining treatments. The lowest yield was noted

Table 1. Effect of integrated nutrient management options on grain yield and yield contributing characters of maize under maize + urd bean-wheat system.

Treatments	Grain yield (t/ha)	No. of cobs (000/ha)	Shelling %	No. of rows/ cob	No of grains/ row	No. of grains/ cob	1000 grain wt
T_1	3528	59.47	84.3	14.40	31.9	459.5	176.8
T_2	3812	62.20	84.6	14.57	32.6	474.2	183.8
T_3	5115	70.50	85.4	15.97	35.3	503.0	198.5
T_4	4262	64.58	85.8	15.43	32.1	494.7	184.7
T_5	3390	57.57	84.9	13.10	31.5	432.1	176.2
T_6	3596	59.67	84.1	13.27	31.5	447.6	191.3
T_7	3872	62.44	84.3	14.37	32.4	466.1	190.2
T_8	4377	66.35	83.7	15.33	33.6	498.5	195.6
T_9	3171	55.79	83.9	12.99	31.5	411.9	168.8
CD <.05%	279	4.28	N S	0.96	0.81	16.3	5.6

in treatment received full crop residue of wheat + 50% recommended fertilizer. Due to nutrient exhaustive nature of maize crop any curtailment in fertilizer dose either by substitution with biofertilizer or crop residue could not support the nutrient need of crops and resulted in lower yield (Shanwad *et al.*, 2010). Addition of FYM in fertilization schedule enhances the efficiency of biofertilizer as well as inorganic fertilizers as it provides adequate source of energy for the microbial processes which confirmed the findings of Mishra *et al*,. 1997.

Urd Yield and attributes

Unlike maize, the highest urdbean grain yield was recorded significantly higher in treatment received Azotobacter + VAM + PSB + 10 tones FYM and 33% N, no P and K through chemical fertilizers which was comparable with the treatment established with the application Azotobacter + VAM + PSB + 75% N, 25% P and 100% K through chemical fertilizers (Table 2).

The application of wheat straw residue with 50% NPK again performed poorest among all the treatments. The yield attributes of urd viz. number of pods per plant, number of grains/pod, 1000-grain weight were remarkably higher under T_7 and T_8 where substitution of N and P by FYM, or Azotobacter + VAM+ PSB or Azotobacter +VAM+PSB+FYM along with chemical fertilizers was made. These results are in close conformity with the results obtained by Reddy *et al.* (2000) and Thavaprakash, and Velayudham (2007).

Wheat grain yield and yield attributes

The residual effect of organic manues/crop residue/biofertilizer applied in maize crop was studied by taking wheat in succession with recommended fertilizer dose. The maximum carry over effect was registered when 10t FYM ha^{-1} added along with recommended dose of fertilizer in Maize + Urd intercrop. As compared to recommended practice of fertilization (T_1) and the combined use of

Table 2. Effect of integrated nutrient management options on grain yield and yield contributing characters of intercrop (Urdbean) under maize + urdbean-wheat system.

Treatments	Grain yield (kg/ha)	No. of branches/ plant	No. of pods/ plant	No. of grains/ pod	Grain weight/ pod	1000-grain weight
T_1	650	6.4	37.13	6.22	0.321	36.87
T_2	668	6.8	37.87	6.18	0.324	37.50
T_3	727	7.3	38.37	6.90	0.373	38.65
T_4	702	6.5	35.53	6.26	0.324	36.92
T_5	619	6.0	31.92	5.70	0.287	35.95
T_6	699	6.3	33.88	6.30	0.328	37.18
T_7	820	7.1	39.38	7.10	0.389	39.17
T_8	825	7.7	40.40	8.08	0.446	39.40
T_9	630	5.9	34.67	5.85	0.300	36.57
CD <.05%	76	0.37	1.77	0.56	0.035	NS

biofertilizers (*Azotobacter* + VAM + PSB) with 10 tones FYM + 33% recommended N, without P and K ($T_{8)}$ about 7.7% higher wheat yields was evidenced in T_3 (Table 3).

Table 3. Effect of integrated nutrient management options on grain yield and yield contributing characters of wheat under maize + urdbean-wheat system.

Treatments	Grain yield (kg/ha)	Effective tillers/m²	Spike length (cm)	No. of spikelets/ spike	No. of grains/ spike	1000-grain weight
T_1	4562	292.5	10.25	22.65	57.00	41.00
T_2	4022	302.9	10.45	20.10	52.85	40.74
T_3	4911	321.1	11.55	21.55	54.45	43.62
T_4	4012	263.9	10.30	20.55	51.85	40.62
T_5	4012	271.7	10.10	18.97	51.00	40.55
T_6	4185	287.3	9.80	18.76	51.90	40.54
T_7	4382	282.1	11.05	20.18	53.60	41.88
T_8	4562	318.5	10.05	19.68	52.93	41.88
T_9	3880	244.4	9.25	18.50	50.80	39.38
CD <.05%	265	16.5	1.15	1.73	2.39	2.56

Treatments T_1, T_7 and T_8 were statistically at par. Application of biofertilizer and/or crop residue with reduced rate of recommended NPK could not support the nutrient need of succeeding crop and resulted in lower wheat yield as compared to 100% NPK. Similar to maize and urdbean, the yield attributes were superior in treatment T_1, T_3 and T_8. The higher wheat grain yield in treatments receiving 10t ha^{-1} FYM as part of fertilizer in maize accounted to slow release of nutrients from FYM and by improving physical condition of soil and enhancing biological properties due to carbon addition through FYM (Srivastava, 2002).

System Productivity and economics

The effect of application of FYM either as addition over NPK or as substitution with N had significant effect on system productivity of Maize+ Urdbean-wheat system (Table 4).

The highest maize equivalent yield (10.4t ha^{-1}) was recorded in treatment supplied with 10t ha^{-1} additional FYM along with recommended NPK, which was 20% higher than recommended NPK alone. The next best treatment, i.e. application of Azotbaztor+VAM+PSB+33% N and no P and K in maize and 100% NPK in wheat gave 11.8% greater yield than recommended NPK. Though system's cost of cultivation did not vary statistically with the treatments but gross and net return varied significantly. Similar to the system productivity the highest net return (45247) with B:C ratio 2.20 was obtained in T_3 followed by T_8. As compared to recommended NPK treatment, 17.8% higher profit was reckoned in T_3 and 8.8% in T_8. Use of FYM is profitable in this experiment because wages are low and FYM is available on-farm. But in many other intensive irrigated systems in India, FYM is not profitable option as

Table 4. Direct and residual effect of IPNS on Economics of maize+ urd-wheat cropping system

Treatments	System productivity (MEY, t/ha)	System's cost of cultivation (Rs. ha^{-1})	System's gross return (Rs. ha^{-1})	System's net return (Rs. ha^{-1})	B :C Ratio
T_1	8627	21748	60206	38458	1.77
T_2	8343	20302	55646	35344	1.74
T_3	10356	20576	65823	45247	2.20
T_4	8750	20668	58050	37382	1.81
T_5	7907	20120	52617	32497	1.61
T_6	8405	20498	54492	34017	1.66
T_7	9066	20232	60356	40125	1.98
T_8	9644	20023	62106	41833	2.09
T_9	7629	19731	51469	31737	1.61
GM	8747	20433	57863	37404	1.83
CD (<0.05)	**754**	**NS**	**5125**	**2965**	**0.15**

MEY=maize equivalent yield

labour and transport cost involved in it surpassed the income derived from it by additional production. The the key determinants of FYM's profitability may be the quality, availability and price of FYM.

Nutrient Uptake and Internal Nutrient use efficiency

The total NPK uptake varied with the crops and treatments, the highest NPK uptake was recorded in wheat (249 kg ha^{-1}) followed by maize (217 kg ha^{-1}) and lowest in urdbean (111 kg ha^{-1}). Among the treatments, the maximum NPK uptake (284.4:56.1:301.6) was recorded in T_3 and lowest in T_9. The next best treatment in terms of uptake was T_1 which was comparable with T_8 (Table 5).

The internal nutrient utilization efficiency was calculated grain yield per kg nutrient uptake by both grain and straw, presented in Table 6 revealed that internal NPK utilization efficiency varied with treatment options and also varied with crops.

In maize, the highest Internal N and K use efficiency was registered in T_3 while P efficiency was highest in T_7. In Urd bean, the NPK use efficiencies were statistically similar in all the treatments. In wheat, the internal nitrogen use efficiency was noted highest in T_8, which was at par with T_3, T_4, T_5, T_6 and T_9. The PUE was recorded maximum again in T_3 but it was significantly superior to all other treatments. Similar to maize the greater

Table. 5.Total N P K uptake in each crop of maize, urdbean and wheat, and system's uptake (kg/ha) as influenced by integrated nutrients management options under maize intercropped with urdbean -wheat system.

Treatments	Nutrient uptake in maize (kg/ha)			Nutrient uptake in urdbean (kg/ha)			Nutrient uptake in wheat (kg/ha)			System's total nutrient uptake (kg/ha)		
	N	P	K	N	P	K	N	P	K	N	P	K
T_1	93.7	19.1	99.7	52.2	8.2	45.1	131.2	26.0	142.1	277.2	53.3	286.8
T_2	92.6	22.3	97.0	54.6	8.6	45.8	97.6	19.3	124.1	244.8	50.2	266.8
T_3	116.6	25.0	121.6	57.2	9.1	47.3	110.6	22.1	132.7	284.4	56.1	301.6
T_4	103.6	21.0	113.5	58.1	9.0	45.4	95.2	18.9	123.0	256.9	48.8	281.8
T_5	89.6	15.5	92.4	49.5	7.7	41.9	94.0	19.7	119.0	233.1	42.9	253.3
T_6	90.6	15.9	94.8	53.3	8.8	44.8	96.9	19.0	120.9	240.7	43.8	260.4
T_7	98.6	16.2	98.4	61.4	10.0	52.7	104.7	20.7	128.5	264.7	46.8	279.6
T_8	100.5	21.5	116.7	63.3	10.3	52.5	99.5	19.6	129.6	263.3	52.4	298.8
T_9	79.4	16.4	82.7	56.2	8.0	41.6	91.7	17.5	117.2	227.3	42.0	241.5
Average	96.1	19.2	101.9	56.2	8.9	46.3	102.4	20.3	126.3	254.7	48.5	274.5
CD <.05%	6.74	2.67	6.24	3.89	0.98	3.03	7.60	2.73	8.20	10.85	2.54	8.90

The internal nutrient utilization efficiency was calculated grain yield per kg nutrient

Table. 6. Effect of integrated nutrients management options on internal nutrient use efficiency (INUE) in maize, urdbean and wheat under maize intercropped with urdbean - wheat cropping system.

Treatments	Nutrient utilization efficiency in maize (kg grain/kg uptake)			Nutrient utilization efficiency in urdbean (kg grain/kg uptake)			Nutrient utilization efficiency in wheat (kg grain/kg uptake)		
	N	P	K	N	P	K	N	P	K
T_1	37.6	184.4	35.4	12.4	79.5	14.4	34.8	175.8	32.1
T_2	41.2	170.9	39.3	12.2	78.1	14.6	41.2	208.2	32.4
T_3	43.9	204.8	42.1	12.7	80.3	15.4	44.4	222.7	37.0
T_4	41.1	203.1	37.6	12.1	78.3	15.5	42.2	212.4	32.6
T_5	37.8	219.0	36.7	12.5	80.1	14.8	42.7	204.1	33.7
T_6	39.7	225.7	38.0	13.1	79.4	15.6	43.2	219.9	34.6
T_7	39.3	239.2	39.4	13.3	82.4	15.6	41.9	212.1	34.1
T_8	43.6	204.1	37.5	13.0	80.3	15.7	45.8	232.5	35.2
T_9	40.0	193.0	38.4	11.2	78.4	15.1	42.3	221.7	33.1
CD <.05%	2.35	3.20	2.85	NS	NS	NS	3.65	5.54	3.45

K efficiency in wheat was recorded in treatment receiving FYM along with NPK.

CONCLUSION

Three main conclusions emerge from this study are, use of recommended doses of NPK alone cannot exploit the yield potential of maize+urdbean-wheat cropping system. Secondly, use of FYM either in addition to NPK or in partial substitution was useful in enhancing the yield of component crop as well as system productivity; however, a better assessment of the relative profitability is needed with respect to variability in cost of FYM. Third, the benefit of application of bio-fertilizer in absence of sufficient organic manure (FYM) could not be obtained and there is need to allow a better comparison of the relative agronomic and economic advantages of inorganic and organic fertilizers, including a better understanding of the benefits of organic amendments (FYM/ Biofertilizer/crop residue) in terms of improved systems which may be profitable, provided the organic materials are used as a complement to a recommended dose of inorganic NPK. In other words, organic amendments are not a substitute for mineral fertilizers and modern, intensive cropping systems should not rely on use of either manure or straw as the primary nutrient source.

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INFLUENCE OF *IN-SITU* GREEN MANURING AND FERTILIZER MANAGEMENT ON AROMATIC RICE

P.M. Paraye[1] and A.K. Chaubey[2]

[1]*Programme Coordinator &* [2]*S.M.S KVK, Bhatapara, Indira Gandhi Agriculture University, Raipur (C.G)*

Abstract

A field experiment was conducted during winter season of 2004 and 2005 at Regional Agricultural Research Station, IGKVV, Raigarh (C.G.), to study the Influence of *insitu* green manuring and fertilizer on aromatic rice (Indira Sugandhit Dhan-9) on growth, yield attributes and yield under sandy clay loam soils. The experimental soil had 188, 7.4 and 212 Kg/ha available N, P_2O_5 and K_2O respectively, with 6.7 pH. The experiment was laid out in randomized block design with 3 replications, having 10 treatments T_1 :Control, T_2 : Sunhemp (*Crotalaria Juncea)* @ 30 kg ha^{-1}, T_3 : (Dhaincha (*Sesbania aculeata*)@ 30 kg ha^{-1} T_4 : T_2 + 33 % RDF, T_5 : T_2 + 66 % RDF, T_6 : T_2 + 100 % RDF, T_7 : T_3 + 33 % RDF, T_8 : T_3 + 66 % RDF, T_9 : T_3 + 100 % RDF, T_{10} : 100 % recommended dose of fertilizer (100: 60: 40 N, P_2O_5 and K_2O kg ha^{-1}). There was significant effect of green-manure crops and different doses of recommended fertilizer on growth, yield attributes and yield of rice crop over control (T_1). The green-manuring of sunhemp + 100 % RDF (T6) recorded maximum value of plant height (108.7 cm), number of panicles (343.3 M^{-2}), number of grain per panicle (103.3), straw (94.5 q ha-1) and grain (60.1 q ha-1) yield. However, it was statistically similar with dhaincha + 100% RDF (T_9), 100% RDF (T_{10}) and 66 % RDF in combination with either sunnhemp (T_5) or dhaincha (T_8). These treatments were statistically superior not only over control (T_1) but also over sunhemp alone (T_2) and dhaincha alone (T_3). The 33 % dose of recommended fertilizer in combination with both green-manure crops recorded significantly higher values of straw and grain yield. The data revealed that the treatment of green manuring + 66 % RDF was at par with no green-manure +100 % RDF, it is thus apparent that 34 % recommended dose of fertilizer can be saved by green manuring.

Key words: Nutrient management, Green manuring, rice

Farm yard manure, compost and green manures (GMs) are the major organic resources that could supplement inorganic fertilizers but availability of the first two is limited (Abrol and Palaniapan, 1988). Despite special efforts at increasing the supplies of FYM and compost, the supply of farm and other organic manure is scarce and costly. Green manure offer greater potential as nutrient supplement that farmers can grow in their own fields. Suitable GMs grown *in situ* and incorporated in the crop field can meet a part of the nutrient requirement, particularly for N and at the same time maintained soil fertility and productivity. It can partially substitutes the nitrogen fertilizer requirement of subsequent crop (Meelu and singh, 1991). The recovery of fertilizer nitrogen for rice is low and deterrent to get the full potential yield. Split application of N fertilizes commensurate with crop growth stage is an useful approach for increasing the efficiency of applied N in rice (Sharma *et al*, 1990). Combined application of organics with inorganics would further augment the N use efficiency. It is therefore necessary to judiciously manage the inflow of inorganic source of nutrients especially the nitrogen. The integrated use of chemical fertilizers and green manuring thus assumes greater significance (Meelu, 1996; Nambiar and Abrol, 1989). Therefore the present study was initiated to find out the effect of split application of recommended dose of fertilizer integrated with green manure-crops on growth parameter and yield of rice.

Materials and Methods

A field experiment was conducted during winter season of 2004 and 2005 at Regional Agricultural Research Station, IGKVV, Raigarh (C.G.), to study the influence of *insitu* green manuring and fertilizer on aromatic rice (Indira Sugandhit Dhan-9) on growth, yield attributes and yields under sandy clay loam soils. The experimental soil had 188, 7.4 and 212 Kg/ha available N, P_2O_5 and K_2O respectively, with 6.7 pH. The experiment was laid out in randomized block design with 3 replications, having 10 treatments T_1 :Control, T_2 : Sunhemp (*Crotalaria Juncea)* @ 30 kg ha^{-1}, T_3 : Dhaincha (*Sesbania aculeata*)@ 30 kg ha^{-1} T_4 : T_2 + 33 % RDF, T_5 : T_2 + 66 % RDF, T_6 : T_2 + 100 % RDF, T_7 : T_3 + 33 % RDF, T_8 : T_3 + 66 % RDF, T_9 : T_3 + 100 % RDF, T_{10} : recommended dose of fertilizer (100: 60: 40 N, P_2O_5 and K_2O kg ha^{-1}). The green manuing crops were sown on of 3rd week of June with a fertilizer level of (20: 50: 20 N, P_2O_5 and K_2O kg ha^{-1}) to ensure good biomass production. The forty day's old green manuring crops was incorporated in to soil just before the transplanting. The transplanting was done with 30 days old seedling on last week of July and harvested in last week of November in both the years.

Results and Discussion

There was significant effect of green-manures alone and in combination with different doses of fertilizer on growth, yield attributes and yield of rice crop over control (T_1) (Table 1). The green-manuring of sunhemp + 100 % RDF (T6) recorded maximum value of plant height (108.7 cm), number of panicles (343.3 m^{-2}), number of grain per panicle (103.3

Table 1. Effect of Influence of *insitu* green manuring and fertilizer management on growth, yield attributes and yield of aromatic rice as influenced by different treatments (Pooled data of 2 years)

Treatment	Plant height (cm)	Panicles m^{-2} (No.)	Grain/ panicle (No.)	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Fresh biomass incorporated in soil t ha^{-1}
T_1 :Control	82.6	241.8	74.8	32.2	46.1	
T_2 : Sunhemp	94.8	275.1	85.4	43.2	61.3	3.0
T_3 : Dhaincha	92.2	265.3	86.6	41.8	57.1	2.5
T_4 : T_2 + 33 % RDF	101.1	293.7	88.9	50.4	75.7	3.0
T_5 : T_2 + 66 % RDF	103.0	320.0	98.0	54.7	83.0	3.0
T_6 : T_2 + 100 % RDF	108.7	343.3	103.3	60.1	94.5	3.0
T_7 : T_3 + 33 % RDF	99.1	288.3	90.5	49.4	79.5	2.5
T_8 : T_3 + 66 % RDF	104.1	317.0	98.3	54.2	85.9	2.5
T_9 : T_3 + 100 % RDF	107.7	337.0	98.7	56.7	93.1	2.5
T_{10} : 100 % RDF	104.2	321.2	95.0	54.9	85.4	
SE m ±	2.5	11.8	4.1	2.1	4.9	
CD at 5 %	7.1	33.5	11.8	6.0	14.1	

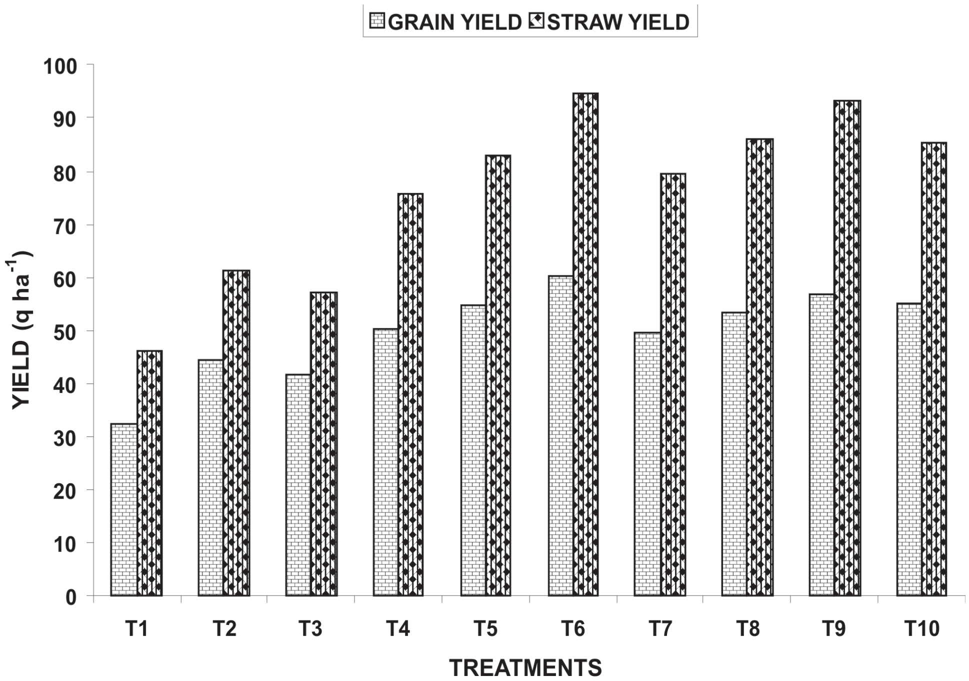

Fig. 1. Effect of Influence of *insitu* green manuring and fertilizer management on grain and straw yield of aromatic rice

), straw (94.5 q ha-1) and grain (60.1 q ha-1) yield. However, it was statistically similar with dhaincha + 100% RDF (T_9), 100% RDF (T_{10}) and 66 % RDF in combination with either sunnhemp (T_5) or dhaincha (T_8). These treatments were statistically superior not only over control (T_1) but also over sunhemp alone (T_2) and dhaincha alone (T_3). The 33 % dose of recommended fertilizer in combination with both green-manure crops recorded significantly higher values of straw and grain yield (Fig 1) while it could not make any significant effect on plant height, number of panicles and grain per plant over their individual response of either sunhemp or dhaincha. Sunhemp alone (T_2) recorded more values of each parameter over dhaicha (T_3) while both were statistically similar, but these were statistically superior over control (T_1). The data revealed that the treatment of green manuring + 66 % RDF was at par with no green-manure +100 % RDF, it is thus apparent that 34 % recommended dose of fertilizer can be saved by green manuring. It confirms the findinging of Meelu and Singh (1991) and Mehta et al (1996) who reported saving of 60 and 40 kg of N/ ha through green-manuring in rice.

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INFLUENCE OF LONG-TERM INTEGRATED NUTRIENT MANAGEMENT ON PHYSICAL PROPERTIES OF SODIC SOIL UNDER RICE-WHEAT CROPPING SYSTEM

ALOK KUMAR AND H.P. TRIPATHI

Department of Agronomy, Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad, Uttar Pradesh 224 229S

ABSTRACT

A study was conducted during 2004-05 to evaluate the effect of integrated use of organic materials and chemical fertilizers applied in rice and chemical fertilizers applied in wheat regularly over 20 years on temporal changes of some important physical properties of sodic soil under rice-wheat cropping system. The study showed that regular incorporation of organic materials (farmyard manure, *Sesbania* green manure, wheat cut straw) alongwith chemical fertilizers before puddling of rice improved the soil aggregation and thereby decreased bulk density which in turn increased saturated hydraulic conductivity and infiltration rate of soil. Farmyard manure and *Sesbania* green manure were found more effective than wheat cut straw. The application of organic materials before puddling for rice helped in improvement of soil physical environment for cultivation of rice and wheat both as indexed by aggregation ,bulk density, hydraulic conductivity and infiltration rate of soil.

Key words: Fertilizers, organic manures, soil physical properties, rice-wheat cropping system

Rice (*Oryza sativa* L.) – wheat (*Triticum aesticum* L. emend. Fiori & Paol.) cropping system is most vital for food security of the Indian sub continent. However, the optimal soil physical environments for rice and wheat differs substantially. Puddling is a common tillage practice in wet land rice which makes the soil soft for transplanting and impervious to water for reducing percolation losses. Although these effects of puddling favour rice growth, they adversely affect the growth of wheat following rice. Continuous cultivation of rice can result in the formation of hard pan below the plough layer which would act as barrier to normal root growth of wheat. The cropping systems, therefore, that include both rice and wheat require special soil management practices like incorporation of crop residues, green manuring, farmyard manure etc. which improves the soil physical condition besides soil fertility (Mandal *et al.,* 1999; Ray and Gupta, 2001).

The impacts of puddling for rice crop on soil physical properties have been reported by several workers (Mishra and Sharma 1997, Bellakki *et al,.* 1998). However, the temporal changes in physical environment of partially reclaimed sodic soil during crop growth are not well documented. This study was undertaken to investigate the long-term effect of puddling and various organic materials on soil physical properties of a partially reclaimed sodic soil, over the growing season, under a rice-wheat cropping system.

MATERIALS AND METHODS

A long-term integrated nutrient management experiment on rice-wheat system was initiated in 1984 at N. D. University of Agriculture and Technology, Faizabad (26° 47' N, 82° 12'

E) in partially reclaimed sodic soil under the cropping system research net work programme. After 20 years of experimentation the study was made to observe the impact of continuous application of organic manures (FYM, wheat straw, *Sesbania* green manure) alongwith fertilizers in rice and only chemical fertilizers in succeeding wheat, on soil physical properties of a partially reclaimed sodic soil. The climate of experimental site is subtropical and subhumid type characterized by hot summer, wet monsoon and dry cool winter. The soil of experimental site is silty loam in texture and taxonomically classified as Typic Ustochrept. Initially, the soil (0-15 cm) had a pH 8.8, EC 0.50 dsm^{-1}, CEC 17.1 c mol (p^{+}) kg^{-1}, organic carbon 0.37% and bulk density 1.38 Mg m^{-3}, saturated hydraulic conductivity 2.6 mm hr^{-1} and final infiltration rate 2.1 mm hr^{-1}. The experiment was conducted in a randomized block design with 12 treatments and 4 replications in fixed lay out. However, the present study was carried out only in five treatments, viz. T_1, control (unfertilized unmanured); $T_{2,}$ 100% recommended dose of NPK through fertilizers in rice and wheat both; $T_{3,}$ 50% recommended N applied through farmyard manure (FYM) and 50% NPK through fertilizers in rice and 100% NPK through fertilizers in wheat; $T_{4,}$ 50% recommended N applied through wheat cut straw (WCS) and 50% NPK through fertilizers in rice and 100% NPK through fertilizers in wheat; $T_{5,}$ 50% recommended N applied through *Sesbania* green manure (GM) and 50% NPK through fertilizers in rice and 100% NPK through fertilizers in wheat. The 100% recommended dose for rice and wheat were 120 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1}. The sources of N, P and K fertilizers were urea, diammonium phosphate and muriate of potash, respectively. The nitrogen contents of FYM, wheat straw and *Sesbania aculeata* were analysed every year for calculating their quantity to supply 50% recommended dose (60 kg ha^{-1}) in rice. On the basis of N content, the quantity of FYM, WCS and *Sesbania aculeata* varied in between 10 to 12 t ha^{-1}. *Sesbania aculeata* (45-50 days old), grown in separate field, was incorporated 2-3 days before transplanting of rice. However, FYM and WCS were incorporated in the moist soil about two weeks prior to rice transplanting. Rice and wheat both were raised under irrigated conditions following the recommended package of practices. The crops were harvested from ground level manually by sickle and above ground biomass was removed from the plots of each treatment. The aggregate analysis was carried out by Yoder's wet sieving method and the saturated hydraulic conductivity was determined by constant head method using undisturbed cylindrical cores. The infiltration rate was measured by double ring infiltrometer.

Results and Discussion

Aggregate stability

Results revealed that regular incorporation of organic materials (farmyard manure, wheat cut straw, *Sesbania* green manure) alongwith fertilizers to rice crop for 20 years significantly increased coarse (1-8 mm) water stable aggregates (WSA) by 45-63% and fine aggregates (0.25-1.0 mm) by 28-45% over 100% NPK through chemical fertilizers alone. The higher values of mean weight diameter (0.85-0.95 mm) were observed in organic manure treated plots as compared to 100% chemical fertilizers (0.63 mm) alone. The decomposition products of organic materials and increase in organic carbon content are most likely responsible for improvement in aggregate stabilization (Boparai *et al.*, 1992; Bellakki *et al.*, 1998). Mishra and Sharma (1997) reported that certain polysaccharides formed during decomposition of organic residues by microbial activity as well as the cementing action of microorganisms help in binding the soil particles together and encourage aggregation.

Among the various organic materials, *Sesbania* green manure (GM) and farmyard manure (FYM) were found more effective in improving soil structure than wheat cut straw(WCS). The organic resins secreted during decomposition of *Sesbania* plant parts have better binding effect (Mandal *et al.*, 1999; Ray and Gupta, 2001). The continuous application of NPK fertilizers alone for 20 years also showed significant increase both in the fine as well as the coarser aggregates over unfertilized treatment. The beneficial effect of balanced fertilizers on soil structure may be because of the role played by phosphate ions in binding of soil particles or due to greater amount of root (organic) residues produced in fertilized plots resulting in aggregate formation (Mishra and Sharma, 1997).

Data (Table1) indicated that tillage operations and other cultural practices for wheat cultivation reduced the amount of coarser aggregates (>1.0 mm) and increased the amount of finer aggregates (<1.0 mm) in all treatments. At the stage of wheat harvest, the maximum mean weight diameter (MWD) value (0.78 mm) in FYM and GM treated plots showed that beneficial effect of organic materials, applied in rice, carried on during wheat cultivation also.

Bulk density

Continuous application of 100% NPK fertilizers alone for 20 years significantly reduced the bulk density than in unfertilized plots (Table 2). The regular incorporation of organic materials (FYM, WCS, *Sesbania* GM) in combination with chemical fertilizers to rice crop for 20 years significantly decreased the bulk density over chemical fertilizers alone. Lowering of bulk density in fertilized and manured plots may be due to higher organic carbon, more pore space and

Table 1. Effect of long-term integrated nutrient management practices on water stable aggregates (%) and mean weight diameter (mm) at rice and wheat harvest under rice-wheat system

Treatment	Rice harvest			Wheat harvest		
	Water stable aggregates (%)		Mean weight diameter (mm)	Water stable aggregates (%)		Mean weight diameter (mm)
	Coarse (1.0–8.0 mm)	Fine (0.25-1.0 mm)		Coarse (1.0–8.0 mm)	Fine (0.25-1.0 mm)	
T_1: Control	7.5	14.3	0.38	8.0	13.1	0.40
T_2: R_{100} W_{100}	13.9	15.4	0.63	10.7	16.0	0.51
T_3: $R_{50+50FYM}$ W_{100}	22.9	22.3	0.92	19.0	24.5	0.78
T_4: $R_{50+50WCS}$ W_{100}	20.1	19.8	0.85	16.6	23.2	0.72
T_5: $R_{50+50GM}$ W_{100}	22.7	20.8	0.95	18.7	22.8	0.78
CD (P=0.05)	2.9	3.1	0.11	2.7	2.1	0.08

Table 2. Effect of long-term integrated nutrient management practices on bulk density of surface (0-10 cm) soil at different stages of rice-wheat system

Treatment	Bulk density (Mg m^{-3})					
	RT	40 DRT	RH	WS	40DWS	WH
T_1: Control	1.31	1.59	1.51	1.36	1.47	1.45
T_2: R_{100} W_{100}	1.27	1.56	1.43	1.33	1.43	1.41
T_3: $R_{50+50FYM}$ W_{100}	1.23	1.47	1.35	1.30	1.36	1.34
T_4: $R_{50+50WCS}$ W_{100}	1.20	1.50	1.36	1.31	1.39	1.36
T_5: $R_{50+50GM}$ W_{100}	1.22	1.46	1.33	1.28	1.37	1.33
CD (P=0.05)	0.03	0.05	0.04	0.03	0.05	0.04

Initial value (July, 1984) – 1.38 Mg m^{-3}
RT- rice transplanting, 40 DRT- 40 days after rice transplanting, RH- rice harvest, WS- wheat sowing, 40 DWS- 40 days after wheat sowing, WH- wheat harvest

good soil aggregation (Mishra and Sharma, 1997). Among the various organic manures, the addition of *Sesbania* green manure showed more reduction in bulk density than that due to wheat straw and FYM incorporation at all the stages. Incorporation of green manuring plants and crop residues keep the soil particles apart and increase apparent specific volume of the soil as a result of which bulk density is decreased (Boparai *et al.*, 1992; Mandal *et al.*,1999) The data (Table 2) also reflected that organic manures, applied in rice, had their positive residual influence on bulk density during succeeding wheat crop.

Results (Table2) revealed that in surface layer (0-10 cm) puddling initially decreased the bulk density, which later increased to a value more than the initial. The initial decreased was due to dispersion of finer soil particles caused by puddling. Later, the dispersed particles settled down and make the soil more compact (Ray and Gupta, 2001). At the stage of rice harvest, the bulk density reduced considerably in all the treatments due to extensive and deep cracking in surface layer on drying of rice soil. The conventional tillage operations of the puddle soil for wheat sowing decreased the bulk density which then increased and later decreased. The decrease in bulk density due to tillage was because of loosening of soils, which reconsolidated after first irrigation and increased the bulk density. The later decrease in bulk density might be due to root activity.

Hydraulic conductivity

The treatment effects on aggregation and bulk density were also well reflected on hydraulic conductivity (Table 3). Incorporation of organic materials (FYM, WCS, GM) with fertilizers (50:50) regularly for 20 years in rice crop also resulted in significantly higher hydraulic conductivity over 100% NPK fertilizers alone. Results (Table 3) also revealed that continuous application of chemical fertilizers alone for 20 years had significantly higher saturated hydraulic conductivity of surface layer over unfertilized plots. The increase in hydraulic conductivity was due to reduction in bulk density and increase

Table 3. Effect of long-term integrated nutrient management practices on saturated hydraulic conductivity of surface soil at rice and wheat harvest

Treatment	Hydraulic conductivity ($mm\ hr^{-1}$)	
	Rice harvest	Wheat harvest
T_1: Control	2.9	6.3
T_2: R_{100} W_{100}	4.1	8.4
T_3: $R_{50+50FYM}$ W_{100}	5.7	9.5
T_4: $R_{50+50WCS}$ W_{100}	5.1	9.1
T_5: $R_{50+50GM}$ W_{100}	5.9	9.8
CD (P=0.05)	0.5	0.9

Initial value (July, 1984) – 2.6 $mm\ hr^{-1}$

in organic carbon content of soil which subsequently increase the porosity of soil as reported by Mishra and Sharma (1997) and Bellakki *et al.* (1998). Among the organic manure treatments, the *Sesbania* green manure and FYM were found more effective. Prasad (1994) and Boparai *et al.* (1992) also reported that application of *Sesbania aculeata* as green manure or FYM alongwith fertilizers has favourable effect on the hydraulic conductivity of soil.

During rice-wheat cropping, puddling for rice reduced the hydraulic conductivity (HC) of soil as puddling reduces non-capillary pores responsible for transmission of water in soil. Results revealed a considerable increase in hydraulic conductivity by wheat cultivation. The improvement in hydraulic conductivity could be associated with the extensive deep root system of wheat which resulted in loosening of the soil. The higher values of hydraulic conductivity in organic manure treated plots at the time of wheat harvest clearly indicated that beneficial effect of organic materials, applied in rice, persisted in wheat also.

Infiltration

Results (Table 4) revealed that puddling for rice reduced the water infiltration rate considerably. Puddling causes reorientation of the finer soil particles which seal the pore spaces and make the surface layer impervious to water. In general, the regular incorporation of organic materials (FYM, WCS, *Sesbania* GM) alongwith chemical fertilizers (50:50) for 20 years significantly increased the final infiltration rate over chemical fertilizers

Table 4. Effect of long-term integrated nutrient management practices on final infiltration rate of soil at different stages of rice-wheat system

Treatment	Final infiltration rate ($mm\ hr^{-1}$)				
	40 DRT	RH	WS	40DWS	WH
T_1: Control	0.6	2.5	12.0	5.0	3.0
T_2: R_{100} W_{100}	1.2	3.0	15.0	5.5	4.5
T_3: $R_{50+50FYM}$ W_{100}	1.6	4.5	18.0	6.0	6.0
T_4: $R_{50+50WCS}$ W_{100}	1.8	4.0	16.0	6.0	5.0
T_5: $R_{50+50GM}$ W_{100}	1.9	5.5	17.0	7.0	6.5
CD (P=0.05)	0.3	0.6	2.0	0.5	0.6

Initial value (July, 1984) – 2.1 $mm\ hr^{-1}$
40 DRT- 40 days after rice transplanting, RH- rice harvest, WS- wheat sowing, 40 DWS- 40 days after wheat sowing, WH- wheat harvest

alone. The addition of organic matter increased aggregate stability and reduced bulk density of soil which possibly increased the rate of water infiltration (Boparai *et al.*, 1992). The incorporation of farmyard manure, crop residues or green manuring of *Sesbania aculeata* significantly increased the water intake rate due to improvement of soil structure and formation of channels after the decay of green manure plant parts and straw residues in rice - based cropping systems (Mishra and Sharma, 1997).

The continuous application of 100% NPK fertilizers alone for 20 years significantly enhanced the final infiltration rate over unfertilized plots. The application of balanced dose of fertilizers indicating the beneficial role of increased root biomass in enhancing the infiltration rate over unfertilized plots.

On comparison the infiltration rate and cumulative infiltration at different stages (Table 4), it was found that at harvest of rice and wheat both, the water intake rate was comparatively higher in each treatment than at 40 days after rice transplanting stage. This might be attributed to extensive deep cracking in soil surface at the time of harvest which facilitated the rapid entry of water into the soil.

The application of organic sources viz. farmyard manure, *Sesbania* green manure, wheat straw before puddling for rice alongwith NPK fertilizers helped in improvement of physical environment of sodic soil for cultivation of rice and wheat both as indexed by aggregation, bulk density, hydraulic conductivity and infiltration rate of soil.

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POSSIBLE ALTERNATIVE CROPPING SYSTEMS FOR FARMERS OF SEMI ARID HARYANA– INDIA

S.K. Yadav*, Pawan Kumar and Manoj Kumar

Department of Agronomy, CCS Haryana Agricultural University, Hisar -125004, India

Abstract

A six year study (2000-01 to 2005-06) was undertaken in semi arid Haryana, India to identify the cropping system(s) which may be more remunerative, eco friendly and sustainable over existing cropping system(s) and are farmer's friendly so that they may be convinced to shift to the new cropping system(s). The study indicated that pearlmillet-potato-green gram was profitable and efficient cropping system over prevalent cropping systems viz. cotton-wheat and pearlmillet-wheat. It gave wheat equivalent yield of 18340.1 kg ha^{-1} and profitability of Rs 56012.8 while the same values for cotton-wheat and pearlmillet-wheat were 9942.2 and 7129.3 kg ha^{-1} and 44269.6 and 34374.4 Rs ha^{-1}, respectively. The cropping system soybean-wheat-cowpea (fodder) was better to pearlmillet-wheat cropping system in terms of both crop yield and profit. Soybean-wheat-cowpea(f) had also been a good cropping system with wheat equivalent yield of 9725.5 kg ha^{-1} and net profit of Rs 40374.4 ha^{-1}. Under comparatively less availability of irrigation water pearlmillet-mustard was found to be promising cropping system with wheat equivalent yield of 6851.5 kg ha^{-1} and profitability of Rs 31100 ha^{-1}. Pearlmillet-fieldpea-maize (fodder) cropping system did not perform well over a period of six years.

Key words: Cropping systems, wheat equivalent, profitability, economic efficiency

Diversification in agriculture is a continuous process since the advent of agriculture to manage soil health, water and other natural resources (Yadav *et al*., 2000, Panda, 2001 and Grover *et al*., 2002). It also meets the changing human tastes/needs. Haryana is an agriculturally advance state of India and geographically very well placed i.e. close to national capital. The food requirement of these cosmopolitan communities/ groups residing in the vicinity is diverse and therefore to meet their needs the continuity in crop diversification is eminent and is clearly visible through changing area under different cropping systems over a period of time (Annon. 1966-67 and Annon. 2004-05). In 1966-67, the major rainy season crops (July to October) were pearlmillet (48%), sorghum (15%), rice (10%) and cotton (10%), while in 2004-05 the area under pearlmillet declined to 27% and that of cotton increased to 34% and rice to 24%. Similarly in winter season crops (November to April), the area under wheat has risen from 33% to 64%; mustard from 9% to 19% while the reversal took place in chickpea area which declined from 48% to 14% during the same period. The rice-wheat, cotton-wheat and pearlmillet-wheat cropping systems have established in Haryana but now these cropping systems are not proving farmers' friendly due to higher water need and susceptibility to insects and pests and adverse effect on soil health. Moreover, in the new millennium with the opening of Indian markets to the world there will be enormous pressure on Indian farmers to produce higher quantum of quality food at low cost from shrinking land and natural resources to meet the need of

*Corresponding author: Professor & Head, Agronomy (yadavask@hau.ernet.in or yadavask@gmail.com)

ever growing population and export to earn foreign exchange to meet the out flow particularly on petroleum products.

In India the technocrats and planners are of the view that agriculture must diversify into more commercial sense with the objective of producing higher quantum of quality food at sustainable level to enhance profitability. Therefore the need of the hour is to develop cropping system(s) with higher productivity, sustainability and economic viability for semi arid areas and therefore an attempt has been made to study the productivity, sustainability and viability of different cropping systems which may include food crops, cash crops, oil seeds and vegetables.

Materials and Methods

Site and soil characteristics

Field experiments were conducted for six years (2000-01 to 2005-06) at the Research Farm of CCS Haryana Agricultural University, Hisar, India, located at 74 27' 28" East longitude, 27 30' East latitude, 215.2 m altitude and the mean annual rainfall is 450 mm and most of it (around 80 per cent) is received in rainy season (July to September). The monthly rainfall during the study period for Hisar is given in Table 1. The area is characterized as semi-arid.

The soil has been classified as a Typic Haplustepts, loosely aggregated with sandy loam texture. The surface (0 – 15 cm) soil layer has 60.4 % sand, 16.9 % silt and 22.7 % clay. The slope of the study area was less than 1%. The organic carbon content of the surface layer (0–15 cm) was 0.38 %. The available nitrogen, phosphorus and potash in surface layer was 122.3, 17.0 and 260.9 kg ha^{-1}, respectively. The soils had no salinity or drainage problem.

Table 1. Monthly distribution of rainfall (mm) at the experimental site during the study period of 6 years.

Months	Crop seasons						Total	Mean
	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06		
July	59.9	209.8	12.9	279.5	-	195.3	757.4	126.33
August	8.7	133.3	22.6	119.6	86.6	9.4	380.2	63.37
September	4.7	26.2	35.9	25.2	41.0	181.3	314.3	52.38
October	-	2.5	-	-	36.4	-	38.9	6.48
November	-	-	-	-	-	3.2	3.2	0.53
December	-	-	10.0	8.6	2.0	-	20.6	3.43
January	15.0	-	6.4	16.9	22.2	-	60.5	10.08
February	9.2	35.2	30.2	-	56.5	-	131.1	21.85
March	-	2.1	2.0	-	57.2	27.2	88.5	14.75
April	46.6	-	-	21.0	16.5	-	84.1	14.02
May	102.7	-	39.3	55.1	9.7	69.2	27.6	46.00
June	48.9	168.7	7.2	61.7	71.1	74.7	432.3	72.05

Treatments and crop husbandry

The rainy season, winter season and summer season crops were grown during July to October, October / November to April and April to June, respectively. The crops were sown in well moist field at their recommended sowing times. The experiment was established as a Balanced Incomplete Block Design with seven treatments and four replications. The details of the treatments consisted of seven cropping systems are given in Table 2. The individual plot size was 10 m x 8.1 m with 1 m margins on both sides of plot to curtail run off to adjunct plots. Recommended rates of fertilizers were applied to all the crops each year with nitrogen applied in two split doses, half at planting and the remaining half as top dressing as per recommendation through DAP and urea, respectively. The full dose of phosphorus and potassium were applied as compound fertilizer in the seed row and covered with soil at seeding. Planting was done each year at spacing as per recommendation for individual crop. The crops were thinned as per need and a recommended space was maintained between plants. The crops were harvested at their physiological maturity. Other agronomic operations and plant protection measures followed local recommendations.

Crop Measurements

The comparison among crop sequences were made by converting the yield of all crops into wheat equivalent on current price basis (Yadav and Newaj, 1990). The current rates were used for computing economic viability. The economic efficiency of the systems was calculated by dividing the net returns ha^{-1} of a crop sequence by 365 days.

Table 2. Details of cropping systems in the experiment from 2000-01 to 2005-06.

Treatments	Cropping systems		
	Rainy season	**Winter season**	**Summer season**
Pearlmillet-wheat	Pearlmillet (*Pennisetum glaucum*)	Wheat (*Triticum aestivum*)	-
Pearlmillet-mustard	Pearlmillet (*Pennisetum glaucum*)	Mustard (*Brassica juncea*)	-
Soybean-wheat-cowpea (fodder)	Soybean (*Glycine max*)	Wheat (*Triticum aestivum*)	Cowpea (fodder) (*Vigna unguiculata*)
Sorghum (fodder)-wheat	Sorghum (fodder) (*Sorghum bicolor*)	Wheat (*Triticum aestivum*)	-
Pearlmillet-potato-green gram	Pearlmillet (*Pennisetum glaucum*)	Potato (*Solanum tuberosum*)	Green gram (*Vigna radiata*)
Pearlmillet-field pea-maize (fodder)	Pearlmillet (*Pennisetum glaucum*)	Field pea (*Pisum sativum var. arvense*)	Maize (fodder) (*Zea mays*)
Cotton-wheat	Cotton (*Gossypium hirsutum*)	Wheat (*Triticum aestivum*)	-

Results and Discussion

Crop productivity

Seasonal crop yield

Rainy season

The productivity data in Table 3 represent a mean of yield over a period of six years ranging from 2000-01 to 2005-06. Pearlmillet is one of the main rainy season crop (July to October) in semi-arid areas of Haryana. The mean pearlmillet yield among different cropping systems varied between 2659.2 and 3256.3 kg ha^{-1} (Table 3). The pearlmillet yield was lowest (2659.2 kg ha^{-1}) in pearlmillet-field pea-maize (fodder) cropping system and highest (3256.3 kg ha^{-1}) in pearlmillet-potato-green gram cropping system. The pearlmillet yield with two crops in a year i.e. pearlmillet-wheat and pearlmillet-mustard cropping systems (where the field was fallow in summer season) was moderate and ranged between 3003.8 and 3017 kg ha^{-1} while the yield even with 3-crops in a year was higher where leguminous crop (mung bean) was grown preceding to pearlmillet. The pearlmillet yield in pearlmillet-field pea-maize(f) cropping system was low and it might be due to exhaustive maize(f) grown in summer season. The pearlmillet yield was higher in treatment preceding green gram as compared to the fields kept fallow in summer season indicated that raising of leguminous crop in summer is beneficial in two ways i.e. resulting in higher yield of succeeding pearlmillet and the economic yield received from leguminous crop (Bhargavi *et al.*, 2008). The soybean, sorghum (fodder) and cotton yield of 2179.0, 36781.3 and 1808 kg ha^{-1}, respectively was recorded in soybean-wheat-cowpea (fodder), sorghum (fodder)-wheat and cotton-wheat cropping system, respectively.

Table 3. Productivity of different cropping systems (mean of six years i.e. from 2000-01 to 2005-06).

Cropping systems	Yield (kg ha^{-1})		
	Rainy	Winter	Summer
Pearlmillet-wheat	3017.0	4866.5	-
Pearlmillet-mustard	3003.8	1877.0	-
Soybean-wheat-cowpea (fodder)	2179.0	4967.5	21142.7
Sorghum (fodder)-wheat	36781.3	4964.2	-
Pearlmillet-potato-green gram	3256.3	25479.0	616.4
Pearlmillet-field pea-maize (fodder)	2659.2	1108.3	32056.5
Cotton-wheat	1808.0	4828.2	-

Winter season

Four crops viz., wheat, mustard, potato and field pea were grown in winter season (October-November to April) in various cropping systems (Table 2). Wheat is a major crop of this region in winter season and mean wheat yield in various cropping systems varied between 4828.2 and 4967.5 kg ha^{-1} (Table 3). The wheat yield was almost comparable in soybean-wheat-cowpea (4967.5 kg ha^{-1}) and sorghum (f)-wheat (4964.2 kg ha^{-1}) cropping systems and was higher than cotton-wheat (4828.2 kg ha^{-1}) and pearlmillet-wheat (4866.5 kg ha^{-1}) cropping systems. The other winter season crops *viz.*. mustard, potato and field pea recorded a yield of 1877, 25479 and 1108.3 kg ha^{-1}, respectively. During winter season, higher wheat yield was recorded in sorghum (fodder)-wheat cropping system for the reason that sorghum fodder crop is a short duration crop and the field remained fallow for several weeks before wheat sowing. The highest wheat yield in soybean-wheat-cowpea(fodder) might be due to two leguminous crops in this system. The wheat yield was slightly stressed in intensive and exhaustive cropping system viz. cotton-wheat. The field pea did not appear to be a successful and promising crop, however, mustard and potato were successful crops in winter season in this area (Annon., 2005-06).

Summer season

During summer season (April – June) three crops viz., cowpea and maize for fodder and green gram for seeds were grown in soybean-wheat-cowpea (fodder), pearlmillet-field pea-maize (fodder) and pearlmillet-potato-green gram cropping systems, respectively (Table 3). Cowpea and maize gave a fodder yield of 21142.7 and 32056.5 kg ha^{-1} and green gram gave a seed yield of 616.4 kg ha^{-1}.

Wheat equivalent yield of cropping systems

The different crops grown in the same season had differential yield potential and economic value and therefore for fair comparison among different cropping systems, the yield of all the crops were converted into wheat equivalent on price basis (Yadav and Newaj, 1990). It was noted that the mean wheat equivalent yield over a period of six years from 2000-01 to 2005-06 varied between 6851.5 and 18340.1 kg ha^{-1} among various cropping systems (Table 4). The highest yield of 18340.1 kg ha^{-1} was recorded in pearlmillet-potato-green gram cropping system and lowest yield of only 6851.5 kg ha^{-1} was recorded in pearlmillet-mustard cropping system. Comparatively lower wheat equivalent yield of 7014.2 and 7129.3 kg ha^{-1} was also recorded in pearlmillet-field pea-maize (f) and pearlmillet-wheat cropping

Table 4. Wheat equivalent yield of different cropping systems from 2000-01 to 2005-06, mean system productivity (kg ha^{-1} day^{-1}) and net returns (Rs ha^{-1})

Cropping system	Cropping years								
	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	Mean of 6-yrs	Mean system produ-ctivity	Mean net returns
Pearlmillet-wheat	6568.8	7425.3	7794.5	7527.5	6842.0	6617.5	7129.3	19.5	34374.4
Pearlmillet-mustard	5608.0	7231.9	7237.6	6790.1	6342.7	7899.1	6851.5	18.8	31100.0
Soybean-wheat-cowpea (fodder)	9214.4	8881.3	11375.6	10111.1	9399.8	9372.2	9725.5	26.7	40374.4
Sorghum (fodder)-wheat	7949.9	8279.6	8836.9	8563.1	7859.3	7213.2	8116.9	22.2	34570.4
Pearlmillet-potato-green gram	18469.1	14747.7	20295.7	19683.3	23790.2	13054.9	18340.1	50.3	56012.8
Pearlmillet-field pea-maize (fodder)	7017.1	5589.1	6421.1	8762.0	7301.5	6994.1	7014.2	19.2	21236.0
Cotton-wheat	8107.1	7611.9	9592.5	12585.4	10337.9	11418.5	9942.2	27.2	44269.6
CD (p=0.05)	592.4	563.6	638.8	538.6	667.2	468.2	-	-	-

systems, respectively. However comparatively higher yield had been recorded in soybean-wheat-cowpea (fodder) (9725.5 kg ha^{-1}) and cotton-wheat (9942.2 kg ha^{-1}) cropping systems. Moderate wheat equivalent yield of 8116.9 kg ha^{-1} was recorded in sorghum (fodder)-wheat cropping system. Almost similar trend was observed during the six years of experimentation (Table 4). Highest wheat equivalent yield in pearlmillet-potato-green gram cropping system was mainly due to high yield potential and economic value of produce in this cropping system. Pearlmillet-mustard cropping system had low yield potential and therefore resulted in low wheat equivalent yield. The wheat equivalent yield of other cropping systems was also related to their yield potential and economic value of the produce (Gangwar *et al*. 2003 and Gangwar *et al.* 2004).

System productivity

System productivity represented by wheat equivalent yield in kg ha^{-1} day^{-1} had a wide range of 18.8 to 50.3 (Table 4). The pearlmillet-potato-green gram cropping system had 50.3 kg ha^{-1} day^{-1} productivity which was 267.6 and 84.9 per cent higher than the lowest and next best cropping system. The system productivity other than pearlmillet-potato-green gram cropping system varied between 18.8 and 27.2 kg ha^{-1} day^{-1}. The cropping systems viz. pearlmillet-mustard, pearlmillet-field pea-maize (fodder) and pearlmillet-wheat had system productivity less than 20 kg ha^{-1} day^{-1}, and soybean-wheat-cowpea (fodder) and cotton-wheat had system productivity around 27 kg ha^{-1} day^{-1}. The system productivity in pearlmillet-potato-green gram was very high and was more than 90% higher than all other cropping systems indicating its clear-cut superiority, which may be due to its high yield potentiality (Jamwal, 2005).

Economic Benefits

Net returns

The average net return per hectare from different cropping systems had a wide range of Rs 21236 to 56012.8 (Table 4). Significantly highest net return of Rs 56012.8 ha^{-1} was recorded in pearlmillet-potato-green gram cropping system and was followed by cotton-wheat with a net return of Rs 44269.6. The soybean-wheat-cowpea (fodder) also gave good net return of Rs 40374.4 ha^{-1}. Very low net return of Rs 21236 ha^{-1} was recorded in pearlmillet-field pea-maize (fodder) cropping system. The moderate net return of Rs 34374.4, 31100 and 34570.4 ha^{-1} was recorded in pearlmillet-wheat, pearlmillet-mustard and sorghum (fodder)-wheat cropping systems, respectively (Gawai and Panwar, 2005).

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EFFECT OF NITROGEN CUM PHOSPHORUS LEVELS AND ZINC APPLICATION ON PRODUCTIVITY OF WHEAT (*TRITICUM AESTIVUM L.*)

Braj Raj Singh, S.K. Chauhan and S.K. Shiroti

Management of Salt affected soils and use of saline water in Agriculture (ICAR), R.B.S. College, Bichpuri, Agra-283 105

Abstract

A field experiment was conducted during the *rabi* seasons of 2002-03 and 2003-04 at cropping system Research Project, R.B.S. College, Bichpuri, Agra. The treatments were four nitrogen levels, (o, 50, 100, 150 Kg ha^{-1}) four phosphorus levels and (0, 25, 50 and 75 Kg ha^{-1}) two Zinc levels (0 and 5 Kg ha^{-1}). The results revealed that growth characters i.e. plant height, shoot/m row length, dry matter accumulation (gm) were significantly in higher dose of N, P and Zinc application i.e. 150 Kg N ha^{-1}, 75 Kg P ha^{-1} and 5 Kg Zn ha^{-1}. The yield attributing characters i.e. spike length (cm), spiklets/spike, No. of grain/ spike, grain weight/spike (gm) and test weight were statistically significant in 150 Kg N ha^{-1}, 75 Kg P ha^{-1} and 5 Kg Zn ha^{-1} Over lower doses of these fertilizers. The grain yield, straw yield, biological yield and harvest index so significant in higher dose of N,P and Zn application. On pooled basis 150 Kg N ha^{-1} applications 7.6, 16.4 and 21.7% more grain yield of wheat over 100, 50 and 0 Kg N ha^{-1}. The application of phosphorus 50 kg ha^{-1} showed 6.4 and 7.5% more grain yield over its lower doses of phosphorus. The application of Zn 5 Kg ha^{-1} accrued 8.7% more grain yield over no zinc application. The same results may be found in biological, straw and harvest index in both years as well as pooled basis.

Key words: Nitrogen, phosphorus, zinc, wheat etc.

Nitrogen is a prime nutrient absorbed by wheat crop in large amount (Singh and Singh, 1995) and is the most limiting factor for affecting crop yields. Secondly, the low (poor) nitrogen content in Indian soils, particularly in Agra region of U.P., further accelerates the problem, hence, there is a need of heavy application of nitrogenous fertilizers to meet out the requirement of wheat crop in a given set of cropping system like "pearlmillet-wheat". Any variety of wheat before being recommended for general cultivation for a particular region must be judged for its potential, tolerance against diseases-pests, non-lodging tendencies, nature of response to added fertilizers, irrigation management, improved crop production technology and adoptability to different agro-ecological conditions. Phosphorus is the second important nutrient, next to nitrogen for cereals production. Increase in wheat yield with the application of phosphorus is due to better development of roots. Indian soils also show Zinc (Zn) deficiency on large scale in U.P. the maximum area is now deficient in available Zn. In the light of the above facts present experiment were carried out.

Materials and Methods

A field experiment was conducted for two consecutive seasons of 2002-03 to 2003-04 under the cropping system Research Project (ICAR) at R.B.S. College, Bichpuri, Agra in a permanent lay out at a fixed location. The treatments consisted of all combinations of four nitrogen levels (0,50,100 and 150 Kg N ha^{-1}), four levels of phosphorus

(0,25,50 and 75 Kg ha^{-1}) and two levels of Zinc (0 and 5 Kg ha^{-1}). These treatments were tested in a split plot design with three replications having phosphorus and zinc in main plots and N levels in sub plots. The net plot size was 2.50 x 2.60 m^2.

The soil was sandy loam with a p^H 8.2, low in available N (182.0 kg ha^{-1}), medium in P (16.4kg ha^{-1}) and high in K (112.0kg ha^{-1}). During winter season (wheat crop), full dose of P as per treatment supplied through DAP (18.1 N and 46% P_2O_5), 40 Kg K_2O ha^{-1} through MOP and Zinc through Zinc sulphate were applied at the time of sowing. The half dose of N was given as basal dressing in time of sowing and half also of N was applied the top dressed at the 30 days after sowing. A recommended seed rate of 120 Kg ha^{-1} in wheat (UP-2338) was used after having treated with Agrosan GN (2 g per kg) seed before sowing. The sowing was done on December 4, 2003-04 and December 3 in 2003-04, respectively and harvested on 20 April and 16 April 2002-03 and 2003-04 in respective years.

The rainfall received during season was 35.2 mm 2002-03 and 20.0 mm in 2003-04 from December 17 to March 25 to first year and December 3 to February end in second year respectively.

The nitrogen content (%) in grain and straw, separately was determined by modified Kjeldhal's method (A.U.A.C., Oven dried grain and straw samples of wheat from each plot were well digested in Tri-Acid-mixture (Tenary), Separately for P determination (Jackson, 1973), Vanado-Molybdo-Phosphoric yellow colour method was followed. The colour intersity was read with "Spectronic-20" at 470 mu (i) photometer. Thereafter, a standard curve was prepared with a series of standard solutions. Phosphorus content (%) was worked- out from the standard curve. Potassium (K) content (%) was determined by Jackson 1973. Protein content (%) was computed on multiplying by 5.73 in content (%) of grain and 6.25 in straw of wheat with N content (%) of wheat grain and straw, respectively.

RESULTS AND DISCUSSION

Growth Characters

All the growth characters i.e. plant height, number of shoots per meter row length and dry matter per plant (gm) were increased significantly by application of N,P and Zn in higher levels. The application of N 150 kg ha^{-1} the maximum plant height, No. of plants/m row length and dry matter accumulation/plant (gm) and minimum in O kg N ha^{-1}. The Table-1 further indicated that the application of P upto 75 kg ha^{-1} increase the plant height. No. of shoots and dry matter accumulation/ plant (gm) and minimum in O kg P ha^{-1}. The application of zinc in 5 Kg ha^{-1} the increase the plant height and No. of shoots/m row length over O kg Zn ha^{-1}. The dry matter/plant was 14.1% higher 5 kg Zn ha^{-1} over O kg Zn ha^{-1}.

Yield Attributies

The yield attributing characters of wheat i.e. spike length, spike lets/spike, No. of grain/Spike, grain weight/spike (gm) and test weight were observed in pooled basis (Table-1). The application of N 150, 100 and 80 Kg ha^{-1} did not significant effect of spike length but 14.1% more than in 150 Kg N ha^{-1} over O kg N ha^{-1}, No. of grain/spike at par with 150 and 100 kg N ha^{-1} but 6.1 and 8.5 more in 150 Kg N ha^{-1} compared with 50 and O Kg N ha^{-1}. The grain weight/ spike it results in No of grain/spike in application of N. The same tread also recorded in test weight. The application

Table 1. Growth characters of wheat as affected by N,P and Zn treatments.

Treatments	No of shoots/ m row length	Plant height (cm)	Dry matter (g)/plant	Spike length (cm)	Spiklets spike	No. of grain/ spike	Grain wt./ spike (gm)	Test weight (gm)
N levels (Kg ha^{-1})								
0	67.5	66.0	57.9	11.5	6.1	8.5	3.2	5.1
50	67.5	83.1	13.9	10.4	18.6	6.1	2.6	1.4
100	83.0	83.7	7.7	10.5	18.8	43.4	2.0	42.9
150	85.8	89.3	13.9	10.6	19.1	43.2	1.96	43.3
CD(p=0.05)	8.4	7.0	4.2	0.1	0.7	0.8	0.03	0.9
P_2O_5 levels (Kg ha^{-1})								
0	67.8	67.2	59.0	24.2	37.7	31.3	36.2	20.2
25	72.1	83.4	15.7	13.0	31.1	23.4	31.7	9.5
50	83.2	83.6	3.7	8.6	13.5	7.7	17.9	5.5
75	80.9	88.2	14.0	11.3	21.9	47.4	0.05	45.9
CD(p=0.05)	7.9	9.8	4.6	0.1	1.0	1.2		1.4
Zn levels (Kg ha^{-1})								
0	73.8	78.1	11.3	9.5	3.2	5.5	8	2.1
5	78.2	84.6	14.1	13.7	18.9	42.1	2.06	42.9
CD(p=0.05)	2.8	MS	NS	0.1	0.5	0.9	0.05	0.4

of P significantly increases the yield attributing characters. On an average, application of 75 Kg P ha^{-1} accrued 8.5, 12.9 and 24.8 per cent more spike length over 50,25 and O Kg P ha^{-1} levels. The pooled basis 75 kg P ha^{-1} 13.3, 30.9 and 37.2% more spike lets per spike in wheat crop. The No. of grain/spike so significant the application of 75 Kg P ha^{-1} recorded 7.6, 23.4 and 31.3% more grain/spike over 50, 25 and O kg P ha^{-1}, respectively. In case of grain weight/spike in pooled basis application of 75 kg P ha^{-1} indicated 17.9, 31.6 and 36.2% more grain weight per spike over 50,25 and O Kg P ha^{-1}. The application of 75 Kg P ha^{-1} accrued 5.4, 9.2 and 22.7% more test weight over 50, 25 and O Kg P ha^{-1}. The pooled basis data application of Zn 5 Kg ha^{-1} produced significantly 13.1% more spike length over O Kg Zn ha^{-1}. The 5 kg Zn ha^{-1} recorded 5.5% more grain/spike over O kg Zn ha^{-1}. The application of 5 Kg Zn ha^{-1} 1.8% more test weights over No zinc application.

YIELD

Nitrogen

A critical examination of the Table-2 indicated that the grain yield, straw yield, biological yield and harvest index of wheat increased with increasing levels of nitrogen from 0 to 50, 50 to 100 and 100 to 150 Kg ha^{-1} during 2002-03 and 2003-04, the maximum grain yield of 48.9 q ha^{-1} and 49.6 q ha^{-1} were respectively obtained 49.3 q ha^{-1} being the values of 40.5, 40.4 and 40.5 q ha^{-1} in respective years and pooled. Obviously, in first year, there did not find any significant difference between increased levels of N but in second year, 100 Kg N ha^{-1} application showed its statistically significance over its lower doses of N i.e. 50 Kg N ha^{-1}. On an

Table 2. Effect of N,P and Zn in grain, Straw, Biological and harvest index in wheat crop.

Treatments	Grain yield q ha^{-1}			Straw yield q ha^{-1}			Biological Yield q ha^{-1}			Harvest Index (%)		
	02-03	03-04	Pooled	02-03	03-04	Pooled	02-03	03-04	Pooled	02-03	03-04	Pooled
N levels (Kg ha^{-1})												
0	40.6	40.4	40.5	76.5	74.0	75.2	117.0	116.9	116.9	34.7	34.6	34.6
50	42.1	42.6	42.3	80.1	78.1	79.1	122.1	123.2	122.7	34.4	34.6	34.6
100	45.6	46.0	45.8	84.3	82.2	83.2	129.9	132.1	130.9	35.1	34.8	34.9
150	48.9	49.6	49.3	89.4	88.4	88.3	138.3	135.1	131.7	35.4	39.7	37.4
CD(p=0.05)	5.1	2.5	3.5	6.4	2.5	4.6	11.3	11.4	11.4	MS	0.9	
P_2O_5levels (Kg ha^{-1})												
0	42.2	42.8	42.9	74.2	73.1	73.6	117.4	116.3	116.8	35.9	36.8	36.8
25	43.4	43.4	43.4	82.8	81.6	82.2	126.2	126.3	125.7	34.4	34.7	34.5
50	45.7	46.7	46.2	84.9	82.1	83.5	130.6	129.4	130.0	34.9	36.1	35.5
75	49.9	45.8	5..2	8802	85.9	87.0	133.2	126.3	129.8	33.7	36.2	34.9
CD(p=0.05)	3.0	2.4		10.0	2.2		12.9	11.2	12.0	NS	1.2	
Zn levels (Kg ha^{-1})												
0	42.7	42.6	42.6	80.1	78.1	79.1	122.3	121.2	121.9	34.8	35.1	34.9
5	45.9	46.8	46.3	84.9	83.2	84.1	130.9	127.4	129.2	35.1	36.0	35.8
CD(p=0.05)	2.7	1.7		NS	1.6		8.1	6.1	7.1	NS	NS	NS

average, 150 Kg N ha^{-1} applications showed 7.6, 16.4 and 21.7% more per hectare grain yield of wheat over 100, 50 and 0 Kg N ha^{-1} levels, respectively. The same trends were observed that for straw yield, biological and harvest index in individual year as well as pooled basis. Several workers viz. Singh et al (1996), Balyan and Kumar (2001) and Gangwar et al (2002) have also reported the similar results.

Phosphorus

An inspiration of Table-2 indicated that phosphorus levels had significant effects on per hectare grain yield in both the years. Wherein, during 2002-03 increasing levels of P from 0 to 25, 25 to 50 Kg p ha^{-1} increased the grain yield but there after due to 75 Kg P ha^{-1} there was slightly reduction in grain yield, though non- significant. Application of 50 Kg P ha^{-1} had significant impact over control (P_O). During 2003-04 similar was the position as the first year. On pooled basis it may be stated that application of 50 Kg P ha^{-1} appeared by and large, advantageous from the per hectare grain yield of wheat. Thus, on an average a dose of 50 Kg P ha^{-1} showed 6.4, and 7.5% more grain yield over its lower doses of P i.e. 25 and Kg P ha^{-1} respectively. Several researchers have also confirmed the results of this research piece Sings et al. (1997), Singh et al. (1996), Rain and Bharti (2001) and Singh et al. (2004).

Zinc

In further Table-2 showed that the application of zinc 5 Kg ha^{-1} affected significantly the per hectare grain yield of wheat in two years 2002-03 and 2003-04, against 0 Kg Zn ha^{-1} application.

Thus on an pooled, application of Zn 5 Kg ha^{-1} accured 8.7% more grain yield over no zinc application. The same results may be obtained in straw yield, biological yield and harvest index for Zn application in both as well as pooled basis reported the similar findings Singh and Sakal (1987), Rao and Shukla (1997), Paliwal et al. (2000) and Kurana et al. (2002).

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OCCURANCE OF MUSTARD APHID, [*LIPAPHIS ERYSIMI* (KALT)] ON MUSTARD CROP IN RELATION TO WEATHER FACTORS

ANIL KUMAR* NAVAL SINGH** AND AMIT KUMAR*

*G.S.D.N. Degree College, Parikshatgarh, Meerut
**Project Directorate for Cropping Systems Research, Modipuram, Meerut

ABSTRACT

The severity of mustard aphid *Lipaphis erysimi* (Kalt) is in mustard (*Brassica compestris L.*) crop and its occurrence is highly related with the weather parameters. The population of mustard aphid was counted at weekly interval from the early and main crop. The peak infestation of mustard aphid (18.9/10 cm twig) was recorded in early crop and it was (318.5/ 10 cm twig)in main mustard crop in rabi season. The variable fluctuation in two years was observed largely due to climatic conditions.

Key words: Nitrogen, phosphorus, zinc, wheat etc.

Mustard (*brassica compestris L.)* is an important oilseed crop of India contributing 23% in total oilseed production. More than 3 dozen insect pests infest the crop at various growth stages. Mustard aphid is most serious and regular pest of mustard crop in *rabi* season in western Uttar Pradesh (Kumar 2004). This pest causes 35.4% to 73.5% losses in mustard yield amounted to 900 crores per annum in India. The occurrence of mustard aphid is largely dependent on the environmental conditions. The aphids multiplies rapidly and the peak population is recorded from the December to mid March in different agro-ecological regions (*Bakhetia and Sekhon*, 1989).For ensure and effective and economical management of this major pests second prevalence was recorded on mustard crops in relation to meteorological parameters.

MATERIAL AND METHODS

Two field experiments were conducted in Meerut region during the crop season in 2003-04 and 2004-05. The first experiment was planted in the second week of October and second experiment was planted in the second week of December. Both the experiments were planted in 5mx3m plot size in randomized block design with 30x15 cm line to line and plant to plant spacing respectively. There were four replications. The recommended agronomy practices and uniform dose of fertilizer also applied. The crop was monitored regularly for initial incidence of aphid. The aphid population recorded in 20 plants was selected randomly. In each plot observations were recorded at weekly interval by removing aphid from 10 cm height twig of each plant with the help of camel brush on a white paper sheet.

RESULTS AND DISCUSSION

The population of mustard aphid recorded from 47th to 4th standard week in early crop and 4th to 13th standard week in main crop in both the years the aphid population and weather parameters were averaged fitted in Tables 1&2.

The results indicate that population of *L erysimi* was less in early crop as compared to December sown in both the years. The aphid appeared in the 4th

Table 1. *L. erysimi* on mustard crop in relation to weather factors during 2003-2004

SW	Av.population/ 10cmTerminal sheet	Weather parameters		
		Temperature		R.H(%)
		Max	Min	
47	16..5	25.8	14.2	72
48	19.7	24.9	12.8	80.9
49	30.1	24.1	9.1	83.3
50	40.4	24.2	7.6	85.7
51	48.9	21.1	10	66.4
52	46.1	19.0	8.2	80.1
1	37.8	15.3	5.3	76.2
2	25.4	20.1	7.7	87.7
3	18.9	16.0	11.3	81..2
4	10.6	18.0	7.4	73..8

•Population count based on 25 plants/plot with 4 replications
•Figures in parentheses are square root transformed value

week of November in early-planted crop and increased gradually and attended its peek (48.9) in the 3rd week of December (51.5). The temperature ranged from 21.1 to 10^{0}C and related humidity 66.4% recorded in that time and there after it declined. In main crop the aphid appeared immediately after germination and increased continuously in number and attended its highest peek (318.5) in second week of March. When the temperature ranged from 21.9 to 15.9 ^{0}C and humidity was 74.3%. Thereafter the population started decline. Based on 2 years meteorological observations the

Table 2. *L. erysimi* on mustard crop in relation to weather factors during 2004-2005

SW	Av.population/ 10cmTerminal sheet	Weather parameters		
		Temperature		R.H(%)
		Max	Min	
4	20.4	19.0	12.6	75.3
5	103.7	20.2	13.1	72.6
6	255.2	23.4	18.3	75.8
7	318.5	21.9	15.9	74.3
8	300	25.4	18.4	60.5
9	256.6	28.1	20.5	72.6
10	215.7	28.3	20.7	65.4
11	163.4	30.9	24.1	50.1
12	136.9	30.1	23.4	48.7
13	110.2	32.1	25.7	45.3

climatic factor played a key role in regulating the incidence of mustard aphid. Several reseachers have earlier reported the role of temperature relative humidity and rainfall on the incidence of mustard aphid (*Bakhetia and Sidhu,* 1983,*Singh and Lal,* 1999).

The minimum temperature ranged from 20 to 28^{0}C with related humidity varying from 65 to 70 % was found for rapid multiplication of mustard aphid (*Anonymus,* 1994).

Result show that the aphid is serious problem in main crop when weather parameters are favorable for the development. So growing of early crop may be a key management to protect the mustard crop from *L erysimi.*

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DIVERSIFICATION OF PEARL MILLET (*PENNISETUM GLUCUM* L.) BASED CROPPING SYSTEM IN SEMI ARID ECOSYSTEM OF RAJASTHAN

SURENDRA SINGH*, K.P.SINGH, O.P.GILL AND A.K.NAG

Department of Agronomy, Agricultural Research Station,Rajasthan Agricultural University, Durgapura, Jaipur (Rajasthan) 302018

ABSTRACT

The field experiment was conducted at Agricultural Research Station, Durgapura, Jaipur during 2006-07 and 2007-08 on loamy sand soil for evaluating the most remunerative cropping system for the semi arid ecosystem of Rajasthan. The yield of different crops in various sequences in terms of pearl millet equivalent yield were significantly the highest (15191 kg/ha) under the Cluster bean-rabi Onion crop sequence followed by Pearl millet-Barley- vegetable Cluster bean sequence (14419 kg/ha). Gross returns of different cropping sequences were significantly effected due to crop diversification. The maximum gross returns (Rs 90403 /ha) was achieved under Clusterbean-rabi Onion that was statistically identical with Pearl millet-Barley-vegetable Cluster bean sequence, however, the maximum B: C ratio was accrued by the Green gram-Mustard sequence. The computation of various efficiency measures reveals that the maximum system productivity (63.83 kg/ha/day), relative production efficiency (33.59 %) and employment generation efficiency (31.51 %) were recorded by the Clusterbean-rabi Onion sequence, however the highest economic efficiency (257.33 Rs/ha/day), irrigation water use efficiency (19.52 kg/ha-mm) and land use efficiency (79.73 %)was observed by the Green gram-Mustard sequence. Clusterbean-rabi Onion significantly enhanced organic carbon, phosphorous and potash as compared to initial soil fertility status and traditional crop sequence. On overall basis Clusterbean-rabi Onion crop sequence may be recommended as the most remunerative cropping system for the farmers of semi arid eastern plain zone (Zone IIIa) of Rajsthan state under irrigated condition.

Key Words: Cropping System, Pearl millet Equivalent Yield, Economics, Efficiency measures, Soil fertility

Wheat (*Triticum aestivum* L.)-Pearl millet (*Pennisetum glucum* L.) is an important cropping system occupying an area of about 1.03 million hectares in northern India (Jain and Dhama, 2006). Key (1990) states that a major goal for agricultural research will be to identify and promote cropping system, which sustain soil productivity and minimize deterioration of the environment. Diversification of cropping system is necessary to get higher yield and return, to maintain soil health, preserve environment and meet daily requirement of human and animals (Samui et., 2004).

In semi arid region of Rajasthan generally two or three crops are sown in a year. Pearlmillet-wheat is the predominant cropping system of the zone. To cope up the market need and maximization of farm income, there is an urgent need of diversification of prevailing cropping system with the inclusion of vegetables, cash crops, medicinal crops and green manure crop. Hence the present study was undertaken.

MATERIALS AND METHODS

The field experiment was conducted at Agricultural Research Station, Durgapura, Jaipur during 2006-07 and 2007-08 on loamy sand soil (pH-8.1, EC-0.18 dS/m, PWP-2.01 % at 15 bar and

*Corresponding author: Email: surendrasm2004@yahoo.com

bulk density-1.54 Mg/m^3) under irrigated condition in randomized block design with three replications. There were nine crop sequences tried (Table 1). For raising different crops recommended package of practices of zone were followed. The total rainfall during the year 2006-07 and 2007-08 were 570 and 605 mm. System productivity, economic efficiency, land use efficiency and

Table 1. Treatment details

	Treatments		
S.N.	**Kharif**	**Rabi**	**Summer**
T_0	Pearl millet (*Pennisetum glucum* L.) (Raj-171) (90-30-0)	Wheat (*Triticum aestivum* L.) (Raj-3765) (90-30-0)	Fallow
T_1	Pearl millet (*Pennisetum glucum* L.) (Raj-171) (90-30-0)	Fenugreek (*Trigonella foenum graecum* L.) (RMT-335) (40-40-0)	Okra (*Abelmoschus esculentus* L.) (Vegetable) (Pusa Sawani) (60-30-30)
T_2	Cluster bean (*Cyamopsis tetragonoloba* L.) (RGC-1003) (20-40-0)	Onion (*Allium cepa* L.) (RO-1) (100-50-100)	Fallow
T_3	Moth bean (*Vigna aconitifolia* L.) (RMO-40) (10-30-0)	Wheat (*Triticum aestivum* L.) (Raj-3765) (90-30-0)	Fallow
T_4	Cowpea (*Vigna unguiculata* L.) (RC-19) (10-30-0)	Ajowan or Ajwain (*Trachysppermum amni*) (Gujarat Ajawain-1) (20-30-20)	Fallow
T_5	Cluster bean (*Cyamopsis tetragonoloba* L.) (RGC-1003) (20-40-0)	Chandrasur (*Lipidum sativum* L.) (Local) (30-40-0)	Green gram (*Vigna radiata* L.) (ML-668) (15-40-0)
T_6	Green gram (*Vigna radiata* L.) (ML-668) (15-40-0)	Mustard (*Brassica juncea* L.) (Bio-902) (60-30-0)	Fallow
T_7	Groundnut (*Arachis hypogea* L.) (M-335) (20-60-0)	Isbgoal (*Planto ovata* L.) (GI-1) (45-45-0)	Green Manuring (Sesbania sp.)
T_8	Pearl millet (*Pennisetum glucum* L.) (Raj-171) (90-20-0)	Barley (*Hordeum vulgare* L.) (RD-2592) (60-30-0)	Cluster bean (Vegetable) (*Cyamopsis tetragonoloba* L.) (M-83) (20-40-0)

*Figure in parenthesis indicate scientific name, variety and NPK used

Table 2. Yield and economics of different cropping sequences under diversification (Pooled 2006-07 and 2007-08)

S.N	Grain yield (Kg/ha)			Fodder yield (Kg/ha)			Pearl millet Equivalent yield (Kg/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C ratio
	Kharif	Rabi	Summer	Kharif	Rabi	Summer				
T_0	2113	2786	-	5845	4335	-	11343	67490	44031	1.08
T_1	2303	1803	270	6163	3432	-	13152	78269	49534	1.73
T_2	1140	16840	-	2460	-	-	15191	90403	55693	1.61
T_3	643	2606	-	1038	3820	-	7727	45939	27429	1.48
T_4	830	541	-	1407	1817	-	4493	26787	12937	0.94
T_5	1249	1020	222	2790	2086	-	7346	43817	25487	1.39
T_6	934	2202	-	1326	4358	-	11713	69902	52238	2.96
T_7	1808	1350	-	1771	2309	-	7349	43696	18807	0.76
T_8	2167	3250	2237	5984	4439	-	14419	85917	55282	1.81
CD (P=0.05)							7927036	-	-	

relative production efficiency were computed by the formulae suggested by Tomar and Tiwari (1990). The irrigation water use efficiency (IWUE) was calculated by dividing the total productivity by total water used by the crops in the particular sequence. Employment generation was determined dividing the total man days employed for the system by 365 days and expressed in percent.

RESULTS AND DISCUSSION

Pearl millet Equivalent Yield (PEY)

A significant variation in PEY was observed among the different cropping systems (Table-2). The pooled mean yield of different crops in various sequences and their production in terms of pearl millet equivalent yield were significantly the highest (15191 kg/ha) under the Cluster bean-rabi Onion crop sequence followed by Pearl millet-Barley- vegetable Cluster bean sequence (14419 kg/ha). The lowest PEY was recorded in case of Cowpea-Ajawain sequence. Similar results were reported by Prasad et al.,(2002)

Economics

Data (Table-2) reveals that gross returns of different cropping sequences were significantly affected due to crop diversification. The maximum gross returns (Rs 90403 /ha) was achieved under treatment under treatment T_2 (Clusterbean-rabi Onion) that was statistically identical with Pearl millet-Barley-vegetable Cluster bean, however, the maximum B: C ratio was accrued by the Green gram-Mustard sequence. These results are in consonance with those of Subbiah and Palaniappan (1992).

Efficiency measures

The computation of various efficiency measures (Table-3) reveals that the maximum system productivity (63.83 kg/ha/day), relative production efficiency (33.59 %) and employment generation efficiency (31.51 %)were recorded by the Clusterbean-rabi Onion sequence, however the highest economic efficiency (257.33 Rs/ha/day), irrigation water use efficiency (19.52 kg/ha-mm) and land use efficiency (79.73 %) was observed by the Green gram-Mustard sequence.

Table 3. Efficiency Measures of different crop sequences under diversification of Predominant cropping system (Mean of 2006-07 and 2007-08)

S.N	System Productivity (Kg/ha/day)	Economic efficiency (Rs/ha/day)	Irrigation water Use efficiency (Kg/ha-mm)	Land Use efficiency (%)	Relative Production Efficiency (%)	Employment Generation efficiency (%)
T_0	55.33	214.79	24.13	56.16	0	25.21
T_1	61.75	232.55	13.70	58.36	15.66	19.45
T_2	63.83	234.00	17.87	65.21	33.59	31.51
T_3	40.67	144.36	16.44	52.05	(-) 32.05	20.55
T_4	23.52	67.73	8.17	52.33	(-) 60.49	16.71
T_5	25.24	87.58	9.18	79.73	(-) 35.40	16.44
T_6	57.70	257.33	19.52	55.62	(-) 3.01	15.62
T_7	26.92	68.89	18.37	74.79	(-) 35.37	30.14
T_8	54.62	209.40	13.11	72.33	26.81	23.29

Soil fertility status

The analysis of soil fertility in terms of available organic carbon, phosphorous and potash reveals that Clusterbean-rabi Onion significantly enhanced organic carbon, phosphorous and potash as compared to initial soil fertility status and traditional crop sequence. These results are in confirmation with the findings of Singh et al., (2008).

On overall basis Clusterbean-rabi Onion crop sequence may be recommended as the most remunerative cropping system for the farmers of semi arid eastern plain zone (Zone IIIa) under irrigated condition. Under limited irrigation water condition Green gram-Mustard may be suggested as the next best alternative for the farmers.

Table 4. Changes in soil fertility status at the end of rabi 2007-08 under diversification of cropping sequences

S.N	Organic carbon (%)	Available phosphorus (Kg/ha)	Available potash (Kg/ha)
T_0	0.25	33.72	189.73
T_1	0.33	36.09	195.32
T_2	0.37	37.35	197.47
T_3	0.27	33.66	191.23
T_4	0.28	34.86	193.66
T_5	0.28	35.24	190.83
T_6	0.27	33.93	192.72
T_7	0.32	34.96	193.39
T_8	0.28	34.74	190.88
Initial	**0.25**	**34.67**	**192.22**
CD (P=0.05)	0.023	1.14	2.93

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YIELD AND YIELD ATTRIBUTES OF *ORYZA SATIVA* AND *TRITICUM AESTIVUM* IN RICE - WHEAT SYSTEM AS INFLUENCED BY HERBICIDES AND *SESBANIA ACULEATE* COMBINATION

PURSHOTAM SINGH[1], PARMEET SINGH AND O.P. MISHRA

Department of Agronomy, Gobind Ballabh Pant University of Agriculture and Technology, Pantnagar

ABSTRACT

A field experiment was conducted during the *kharif* and *rabi* seasons of 2001-02 and 2002-03 at Crop Research Center of Gobind Ballabh Pant University of Agriculture and Technology, Pantnagar. Application of herbicides viz Butachlor in rice and Isoproturon in wheat with organic matter through ***Sesbania aculeate*** had significantly suppressed the weed flora viz . *Echinochloa colona* in rice and *Phalaris minor* in wheat, their by giving significantly higher grain yields, yield attributes, harvest index and minimizing weed competition index both in rice and wheat.

Key Words: Herbicides, Rice-Wheat system, *Echinochloa colona, Phalaris minor*

Rice-Wheat sequence is one of the worlds most important cropping system practiced on about 22.5 m ha area in South-Asia and China. It is also the largest cropping system in India covering an area of 11m ha and contributes about 25% of total rice production and 42% of total wheat production of the country. Thus, rice-wheat system is the main system of Agricultural production for food grain in India. This system will also remain a point of significance for self sufficiency in the country. One of the major constraints to crop production is weed infestation. It reduces grain yield either directly or indirectly. Continuous adoption of same rotation coupled with the use of a particular weed management may lead to the intensity and shift in weed flora with respect to time. The practice of growing rice-wheat continuously is responsible for the dominance of a particular weed like *Echinochloa colona* in rice and *Phalaris minor* in wheat. Thus the present investigation was carried out with the objective to study the effect of herbicides with and without organic matter on weed dynamics and yield of rice and wheat.

MATERIALS AND METHODS

A field experiment was conducted during *kharif* and *rabi seasons* of 2001-02 and 2002-03 at the Crop Research Center of Gobind Ballabh Pant University of Agriculture and Technology, Pantnagar. The soil was sandy-loam having pH 7.8, organic carbon 0.69%, available N 266.6 kg/ha, P_2O_5 37.8 kg/ha and K_2O 264.3 kg/ha. The experiment was laid out in Randomized Block Design comprising of seven treatment combinations viz. farmers practice (Butachlor 1.5 kg/ha)— farmers practice(Isoproturon 1 kg/ha); Butachlor fb 2,4-D (0.5 kg/ha 20 days after transplanting)—Isoproturon + 2,4-D with and without organic matter in *kharif* ; Butachlor rotated with Pretilachlor (0.75 kg/ha) fb 2,4-D – Clodinafop (60g/ha) with and without organic matter in *kharif* ; Butachlor fb hand weeding 45 DAT – Isoproturon fb hand weeding 50 days after sowing; and

[1]Assistant Professor, Dept. of Agronomy, SKUAST-Kashmir

weedy—weedy, with three replications. Twenty five days old seedling of rice cultivar Narendra 359 was transplanted on 24th and 10th of July 2002 and 2003 respectively where as wheat cultivar UP 2425 was sown on 10th and 4th of Dec. 2001 and 2002 respectively. One- half of the recommended dose of N and full dose of P_20_5 and K_20 were applied before transplanting/ sowing and remaining amount of N was top-dressed at active tillering stage. In both rice and wheat herbicides were applied with the help of foot sprayer with flat fan nozzle using 600 lit of water/ha. Density and dry weight of weeds was observed by least count quadrate method and the data on weeds was subjected to log_e transformation before analysis. Weed index was calculated on the basis of grain yield.

Results and Discussion

Rice

The mean data of two years reveals that density and dry weight of *Echinochloa colona* and total weeds in general were higher under weedy condition as compared to other treatments. Population and dry matter of *Echinochloa colona* were recorded in all the treatments except treatment butachlor, butachlor fb 2, 4-D + OM through *Sesbania aculeata* and butachlor + hand weeding (Nandal *et al*, 1999). All the treatments significantly reduced the total weed density and total weed dry matter production as compared to weedy conditions. Butachlor fb 2,4-D + organic matter through *Sesbania aculeata* and Butachlor + hand weeding were effective in controlling and reducing dry matter of all the weeds resulting in minimum weed competition index (Table 1). This suppression of weed flora, weed dry weight and minimum weed competition index was due to control of major weeds like *Echinochloa* spp. (Nandal et al, 1998). Butachlor fb 2, 4-D was found best for control of weeds and reduction of dry weight (Raju and Reddy, 1990).

Among herbicide treatments on mean basis butachlor + hand weeding, butachlor fb 2, 4-D+ organic matter through *Sesbania aculeata* and butachlor rotated with Pretilachlor fb 2, 4-D+ organic matter through *Sesbania aculeata* recorded significantly higher dry weight (g/m^2), panicles/m^2, grains/ panicle and weight of grains per panicle, which is evident from the grain yield obtained and harvest index, though there was no significant difference in tillers per m^2.

Significantly higher grain yield and harvest index was recorded under the treatment butachlor + HW at 45 DAT followed by Butachlor fb 2, 4-D + organic matter through *Sesbania aculeata*. The weed index ranged from 0 to 10.9 percent under different herbicide treatments. There was no competition between weeds and crop under treatment Butachlor fb 2, 4-D + organic matter through *Sesbania aculeata* having 3.2 percent weed index and Butachlor rotated with Pretilachlor fb 2, 4-D + organic matter through *Sesbania aculeata* having 5.6 percent weed index.

Wheat

Density and dry weight of *Phalaris minor* and total weeds were highest under weedy conditions as compared to other treatments, whereas the total weed density recorded was highest irrespective of the treatments. The mean data reveals that Isoproturon + hand weeding, Clodinafop fb 2,4-D with and without organic matter in kharif recorded significantly lower density and dry matter of *Phalaris minor* followed by Isoproturon + 2,4-D with organic matter

Table 1. Yield and yield attributes of rice as influenced by weeds and herbicide treatment combinations

(Pooled data of two years)

	Treatments		*Echinochloa colona* (60 DAT)		Total weeds (60DAT)		Rice								
	Rice	Wheat	Density (no./m²)	Dry weight (g/ m²)	Density (no./m²)	Dry weight (g/ m²)	Tillers/ m²	Dry matter g/m²	Panicles/ m²	Grains/ panicle	Weight of grain/ panicle	Grain yield (q/ha)	Harvest index	Weed Index (%)
T_1:	Buta	Iso	0.0(0.0)	0.0(0.0)	0.8(1.95)	1.2(4.65)	198.5	102.20	161.5	148.5	5.0	55.89	41.8	9.5
T_2:	Buta- fb 2,4-D	Iso + 2,4-D	0.4(0.65)	0.7(1.7)	0.7(1.15)	1.1(3.3)	200.0	1044.30	164.5	152.0	5.3	56.92	42.0	7.7
T_3:	Buta- fb 2,4-D + OM	Iso + 2,4-D	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	207.5	1092.40	173.0	175.5	5.9	59.57	42.2	3.2
T_4:	T_2 –with Pretilachlor in rotation	Clodinafop fb 2,4-D	0.7(1.15)	0.4(3.24)	0.9(1.85)	1.4(4.82)	188.5	987.50	148.0	132.0	4.5	55.05	41.3	10.9
T_5:	Treat-4 + OM	Clodinafop fb 2,4-D	0.8(2.0)	0.8(2.97)	0.9(2.0)	1.0(2.97)	203.5	1055.90	168.0	160.0	5.5	58.05	41.5	5.6
T_6:	T_1 + HW 45 DAT	T_1 + HW 45 DAS	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	210.5	1109.20	176.5	191.0	6.2	61.40	43.2	0.0
T_7:	Weedy	Weedy	1.9(6.15)	2.6(12.79)	4.2(86.2)	4.2(70.67)	169.5	847.10	125.0	126.5	4.0	50.99	42.5	17.3
	CD (p=0.05)		0.27	0.19	0.17	0.15	NS	91.41	20.53	14.51	0.60	5.51	0.90	-

Original value in parentheses
OM- Organic Matter
DAS- Days after transplanting

Table 2. Yield and yield attributes of wheat as influenced by weeds and herbicide treatment combinations

(Pooled data of two years)

	Treatments		*Phalaris minor* (60 DAS)		Total weeds (60DAT)		Rice							
	Rice	Wheat	Density (no./m^2)	Dry weight (g/ m^2)	Density (no./m^2)	Dry weight (g/ m^2)	Tillers/ m^2	Dry matter g/m^2	Ear/ m^2	Grains/ ear	Weight of grain/ ear	Grain yield (q/ha)	Harvest index	Weed Index (%)
T_1:	Buta	Iso	5.35 (250)	3.16 (28.49)	5.57 (285)	3.18 (30.46)	218.0	402.8	202.0	40.0	1.4	21.43	36.8	9.9
T_2:	Buta- fb 2,4-D	Iso + 2,4-D	5.42 (256.5)	4.0 (44.18)	5.52 (279.5)	4.00 (44.18)	177.0	351.6	168.5	39.0	1.3	17.75	34.0	24.6
T_3:	Buta- fb 2,4-D + OM	Iso + 2,4-D	4.91 (144.5)	3.40 (33.98)	4.96 (153)	3.47 (35.4)	271.0	517.2	247.5	47.0	1.9	24.53	37.6	0.0
T_4:	T_2 –with Pretilachlor in rotation	Clodinafop fb 2,4-D	3.11 (73)	3.22 (31.48)	4.44 (123)	3.30 (32.27)	204.5	394.5	195.5	40.0	1.4	18.35	34.8	22.0
T_5:	Treat-4 + OM	Clodinafop fb 2,4-D	3.58 (64)	3.12 (31.12)	4.26 (100)	3.22 (32.27)	242.0	476.1	216.0	40.5	1.4	21.50	35.4	13.9
T_6:	T_1 + HW 45 DAT	T_1 + HW 45 DAS	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	317.0	675.0	292.0	55.0	2.1	33.42	37.9	5.6
T_7:	Weedy	Weedy	6.00 (404.5)	5.34 (221.96)	6.13 (465.5)	5.36 (227.16)	143.5	213.3	73.0	34.5	1.1	8.01	29.3	68.0
	CD (p=0.05)		0.54	0.42	0.52	060	47.07	40.34	27.45	2.87	0.20	2.33	3.34	-

Original value in parentheses
OM- Organic Matter
DAS- Days after transplanting

in *kharif* were effective in reducing density and dry weight of *Phalaris minor* as compared to weedy condition. Isoproturon + hand weeding and Clodinafop fb 2,4-D with and without organic matter in *kharif* were effective in suppressing weeds and reducing dry matter production, though minimum weed competition index was observed under treatment Isoproturon + hand weeding and Isoproturon + 2,4-D with and without organic matter in *kharif* (Table2). This suppression of weed flora, weed dry weight and minimum weed competition index was due to control of major weed like *Phalaris minor* (Nandal and Singh 1994). The combination of herbicides and manual weeding i.e. Isoproturon + hand weeding was significantly superior in reducing weed density and dry weight. Among herbicide treatments on mean basis Isoproturon + hand weeding, Isoproturon + 2, 4-D with organic matter through *Sesbania aculeata* and Clodinafop fb 2, 4-D+ organic matter through *Sesbania aculeata* recorded significantly higher number of tillers/ m^2, dry weight (g/m^2), ears/m^2, grains/ ears and weight of grains per ears, which is evident from the grain yield obtained and harvest index.

Significantly higher grain yield and harvest index were recorded under the treatment Isoproturon+ hand weeding, Isoproturon + 2, 4-D with organic matter through *Sesbania aculeata* and Clodinafop fb 2, 4-D+ organic matter through *Sesbania aculeata* The weed index ranged from 0 to 24.6 percent under different herbicide treatments (Table 2). There was no competition between weeds and crop under treatment Isoproturon + 2, 4-D with organic matter through *Sesbania aculeata* having 0 percent weed index and Clodinafop fb 2, 4-D + organic matter through *Sesbania aculeata* having 13.9 percent weed index. There was some reduction in yield which was due to lower temperature, sunshine hours and early rainfall at the time of germination.

Conclusion

Thus, it was concluded that organic matter with proper dose of herbicides i.e. Butachlor fb 2, 4- D + om through *Sesbania aculeata* in rice ; Isoproturon + 2, 4- D with organic matter in *kharif* in wheat at proper time was effective in suppressing the weeds and increasing the grain yield of both rice and wheat.

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RESPONSE OF FOLIAR FEEDING OF MOLYBDENUM AND BORON ON GROWTH AND YIELD OF BROCCOLI (*BRASSICA OLERACIA* VAR.*ITALICA*) CV. AISHWARYA

M.K. SINGH, SUNIL MALIK, VINOD KUMAR* AND I.P. SINGH

Department of Horticulture, Sardar Vallabh Bhai Patel University of Agriculture & Technology, Meerut-250110

ABSTRACT

An experiment was carried out to study the effect of foliar feeding of Molybdenum and Boron on growth and fresh curd yield of broccoli (*Bassica oleracea* var. *italica*) at Horticulture Research Centre, SVBPUAT, Meerut. The maximum plant height of (31.4cm), number of leaves plant^{-1} (18.0), length of leaf (41.4cm), stem diameter (5.8cm), curd diameter (15.9cm), curd weight (313.3g) plant^{-1} and fresh yield of curd (150.4 q ha^{-1}) were recorded with 80:50:50 kg NPK +200 qha^{-1} FYM +200ppm Mo+6ppm B, while it was recorded minimum under control during the investigation.

Key words: Boron, brocolli, molybdenum

Broccoli (*Brassica olracea* var. *italica*) is an important cole crop belonging to family Brassicaceae. The name broccoli refers to young shoots, which morphologically resembles to cauliflower. The heads of broccoli are rich in protein, minerals and vitamins and essential for abundant quantities in human diet. Now-a-days, it is gaining popularity in India due to nutritional value including flavour, taste, carotenoinds and anticancer properties. Area under its cultivation is very limited but increasing day by day. Green sprouting broccoli has a great demand in Indian Vegetable markets. In Western Uttar Pradesh, broccoli is a newly introduced crop and gaining popularity in farmers. Very little information is available on various nutritional aspects. The present study has been made to find out the impact of two important micro-elements Boron and Molybdenum on growth and yield of broccoli.

MATERIALS AND METHODS

A field experiment was carried out during *rabi* seasons 2006-07 and 2007-08 at Horticultural Research Centre, SVBPUAT, Meerut, respectively. The soil of the experimental field was sandy loam, low in available nitrogen (180 kg ha^{-1}), medium in available Phosphorus (18 kg ha$^{-1)}$ and Potassium (175 kg ha^{-1}) with pH 7.6, and organic carbon (0.45%). The one month old seedlings were transplanted in experimental field on dated 3rd and 4th Nov. 2006 and 2007, respectively. The total treatments were tried to asses the effect of foliar application of Mo and B i.e., T_1 (80:50:50 kg NPK+ 200q FYM ha^{-1} + 100 ppm Mo + 5 ppm B), T_2 (80:50:50 kg NPK + 200q ha^{-1} FYM + 100 ppm Mo + 6 ppm B), T_3 (80:50:50 kg NPK + 200 q ha^{-1} FYM + 100 ppm Mo + 7 ppm B), T_4 (80:50:50 kg NPK + 200 q ha^{-1} FYM + 200 ppm Mo + 5 ppm B), T_5 (80:50:50 kg NPK + 200 q ha^{-1} FYM + 200 ppm Mo + 6 ppm B), T_6 (80:50:50

*Present address : Project Directorate for Cropping Systems Research, Modipuram, Meerut- 250110

kg NPK + 200q ha^{-1} FYM + 200ppm Mo + 7 ppm B), T_7 (80:50:50 kg NPK + 200q ha^{-1} FYM + 300ppm Mo+ 5ppm B), T_8 (80:50:50 kg NPK + 200q ha^{-1} FYM + 300ppm Mo + 6ppm B), T_9 (80:50:50 kg NPK + 200q ha^{-1} FYM + 300 ppm Mo + 7 ppm B) and T_{10} (80:50:50 kg NPK + 200q ha^{-1} FYM (control), which were replicated thrice. The full dose of phosphorus and potash and half dose of nitrogen were applied at the time of planting and remaining half dose of nitrogen was supplied after 30 days of establishment of seedlings in field. The FYM was applied in field at one fortnight before at the time of field preparation. The data were recorded accordingly and analyzed statistically. The pooled data analysis was carried out on two years of experimentation.

Results and Discussion

Data presented in Table 1 shows that the height of plant (cm), number of leaves, length of leaves (cm) and diameter of stem significantly increased with the increase in the doses of NPK 80:50:50 Kg NPK+ 200q F.Y.M ha^{-1}+ 200ppm Mo+ 6ppm B, and thereafter it gradually decreased with increase of doses of micronutrients. The maximum plant height (31.4 cm), number of leaves (18.0), length of longest leaves (41.4 cm) and diameter of stem (5.8 cm) were recorded with treatment 80:50:50 Kg NPK+ 200 q ha^{-1} FYM+ 200 ppm Mo+ 5 ppm B, whereas minimum height of plant (19.6 cm), number of leaves (11.3), length of leaves (30.5 cm) and diameter of stem (3.2 cm) were noticed under control. Similar findings were recorded by Prasad and Yadav (2003) in terms of plant height, number leaves, stem diameter and length of longest leave. It is probably due to the translocation of sugar, starch and nitrogen in plant.

Table 1 reveals that yield and yield attributing characters namely, diameter of curd (313.3 g) and yield of curd (150.4 q ha^{-1}) were highly influenced by T_5

Table 1. Effect of foliar feeding of molybdenum and boron on growth and yield of broccoli (*Brassica oleracia* var.*italica*) cv. Aishwarya (2006-07 & 2007-08 pooled data)

Treatments	Plant height (cm)	No. of Leaves	Length of Longest leaves (cm)	Diameter of stem (cm)	Diameter of curd (cm)	Weight of curd	Yield of Curd q ha^{-1}
T_1	20.8	13.6	32.3	3.8	11.3	221.6	106.1
T_2	23.5	15.0	33.4	4.3	12.8	236.7	110.4
T_3	25.5	15.3	35.6	4.8	13.6	249.3	119.7
T_4	27.6	16.0	38.3	5.1	14.7	286.6	137.5
T_5	31.4	18.0	41.4	5.8	15.9	313.3	150.4
T_6	28.8	16.3	39.7	4.7	14.9	283.3	135.9
T_7	27.2	15.0	38.8	3.8	14.2	271.7	130.3
T_8	25.4	14.3	37.7	3.7	13.9	260.0	124.8
T_9	23.7	14.0	35.8	3.4	12.8	250.0	120.0
T_{10} (control)	19.6	11.3	30.5	3.2	9.6	215.0	103.2
CD at 5%	1.13	1.58	1.28	1.21	0.54	20.1	3.57
SEm ±	0.58	0.81	0.66	0.62	0.28	10.3	1.82

treatment, whereas, minimum diameter of curd (9.6 cm), weight of curd (215g) and yield of crud (103.2 q ha^{-1}) were ranked under control (T_{10}). The results were in close conformity with Prasad and Yadav (2003), Chattopadhayay and Mukhopadhayay (2003) in relation to yield of curd and yield attributing characters. It might be due to translocation of sugar, starch and good amount of ascorbate. Similar results were also obtained earlier by Nie *et al.* (2007); Wenqiang *et al*. (2004) who reported that yield of Cauliflower significantly increased with increase in the level of nutrients and thereafter decreased. It might be due to the increase and decrease of ascorbate in plant body. Bergamine *et al*. (2005) also reported that the relation between Boron and yield was linear and positive.

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SULPHUR REQUIREMENT OF CLUSTERBEAN (*CYAMOPSIS TETRAGONOLOBA*)-WHEAT (*TRITICUM ASTIVUM*) CROPPING SYSTEM UNDER SEMI-ARID TRACT OF RAJASTHAN

N.K. Jain[1] and A.K. Gupta[2]

Department of Agronomy, S.K.N. College of Agriculture, Rajasthan Agriculture University, Jobner (Jaipur): 303 329

Abstract

Soil analysis of 858 samples collected during 2003-06 from 15 villages of Dausa tehsil of Dausa district of Rajasthan (India) revealed that 79.93 per cent soil samples were rated as S deficient, 17.60 per cent under medium category while only 2.47 per cent under high available sulphur status. A field experiment conducted on S deficient soil during 2003-06 on farmer's field to study the sulphur requirement of clusterbean (*Cyamopsis tetragonoloba*)- wheat (*Triticum aestivum*) cropping system revealed that S fertilization up to 45 kg ha^{-1} significantly increased seed and straw yields as well as S uptake by clusterbean. Agronomic efficiency, physiological efficiency and value : cost ratio decreased up to 45 kg S ha^{-1}. S recovery increased up to 30 kg S ha^{-1} (14.0 %) and thereafter declined. Residual effect of sulphur up to 45 kg S/ha significantly improved grain yield by 34.7 per cent and straw yield of wheat by 33.2 per cent over the control.

Productivity, S uptake and apparent S recovery in clusterbean –wheat system increased with the increased level of sulphur up to 45 kg S ha^{-1} while physiological efficiency was higher at 15 kg S ha^{-1}. Agronomic efficiency and value : cost ratio of system increased with increasing S levels up to 30 kg/ha. Sulphur application continuously increased the available sulphur status when applied at 30 and 45 kg S/ha.

Key words: Clusterbean, wheat, uptake, nutrient use efficiency, yield and value: cost ratio.

Sulphur is considered as the fourth major nutrient along with N, P and K for balanced fertilization. It is a key element in plant metabolism and plays important role in the synthesis of amino acids, glycosides and protein configuration. Continuous use of high analysis sulphur free fertilizers in intensive cropping system has depleted the soils of their available S-reserves. The information on inclusion of optimum dose of sulphur with NPK fertilizer application is limited. The present study was therefore, initiated with the objectives of assessing the sulphur status in soils to delineate the sulphur deficient areas in Dausa district of Rajasthan and to determine the sulphur requirement of clusterbean (*Cyamopsis tetragonoloba* L. Taubert) – wheat (*Triticum aestivum* L. emend. Fiori & Paol.) cropping system by the direct and residual effects under semi-arid tract of Rajasthan.

Materials and Methods

The villages falling in Dausa tehsil of Dausa district of Rajasthan where clusterbean - wheat is the major cropping system, were surveyed to collect soil samples (0-15 cm) for analysis

[1]Project Incharge, AICRP on Cropping Systems (ECF), Rajasthan College of Agriculture, Udaipur (Rajasthan)-313 001
[2]Dean, College of Agriculture, Lalsot (Dausa)

of available sulphur and delineation of sulphur deficiency. After surveying, 858 soil samples were collected from 15 villages taking 5 villages at a time in the month of June during each year. Available sulphur in soil was extracted by 0.15 per cent $CaCl_2$ solution and sulphur content was determined by the method of Chesnin and Yien (1950). Soil samples containing 10 mg/kg or less considered as low or deficient in available S and 10-20 mg/kg were medium and those containing more than 20 mg/kg available sulphur were considered high in sulphur status.

A field experiment was conducted during 2003-06 on a farmer's field at Ramsignhpura village in Dausa tehsil of semi-arid eastern plain zone of Rajasthan. The experimental site was loamy sand in texture, having soil pH 6.34-6.70, EC 1.31-1.40 dS/m, organic carbon 0.13-0.18 per cent, available P_2O_5 12.12-16.50 kg/ha, available K_2O 241.08-271.80 kg/ha and available S 12.8-14.3 kg/ha. The experiment was conducted with 4 levels of sulphur (0, 15, 30 and 45 kg/ha) applied to clusterbean every year. The treatments were replicated 5 times in randomized block design. The gross plot size was 6 m x 4.5 m. Clusterbean 'RGC 936' was sown during 2nd to 3rd week of July using seed rate of 12 kg/ha with a spacing of 30 x 10 cm during each year. Nitrogen @ 25 kg/ha through urea and diammonium phosphate, phosphorus @ 60 kg/ha through single super phosphate and diammonium phosphate and potassium @ 20 kg/ha through muriate of potash were applied at the time of sowing. The sulphur was applied through single super phosphate at the time of sowing as per treatments. All the packages of practices were followed as per recommendations.

After harvesting of clusterbean, wheat (Raj 3077) was sown in the same plots after ploughing once and harrowing twice the field to study the residual effect of sulphur fertilization. A uniform dose of 90 kg N, 20 kg P_2O_5 and 20 kg K_2O/ha was applied through urea, diammonium phosphate and muriate of potash, respectively. Wheat was sown in the third week of November using seed rate of 100 kg/ha at a spacing of 22.5 cm during all the three years. The collected plant samples of each crop were dried, ground and digested for chemical analysis of sulphur. The uptake of sulphur by clusterbean and wheat was estimated by multiplying sulphur content with corresponding yields. Apparent recovery of sulphur, agronomic efficiency, physiological efficiency and value : cost ratio were also worked out as per the standard formulae.

Results and Discussion

Sulphur status of soil

Chemical analysis of 858 soil samples collected from various villages of Dausa tehsil of Dausa district of Rajasthan revealed that available sulphur status ranged from 1.63 to 24.18 mg/kg soil (Table 1). The sulphur deficiency was highest in Shaikhpura and Rajpuria villages (98 %) while it was lowest in Bagpura-Chhareda (42 %). The overall status of Dausa tehsil revealed that out of the 858 soil samples, 79.93, 17.60 and 2.47 per cent samples were in low, medium and high sulphur status, respectively. The maximum incidence of low category of soils was mainly due to intensive cultivation without use of S-containing fertilizers and growing of

Table 1. Available sulphur status of soil in Dausa tehsil of Dausa district of Rajasthan (2003-04 to 2005-06)

S.No.	Villages	No. of soil samples	Available S (mg/kg)			Per cent samples			
			Min.	Max.	Average	Low	Medium	Low & medium	High
1	Ramsinghpura	50	3.46	11.98	7.19	94.0	6.0	100.0	-
2	Malwas	50	2.68	13.14	6.31	94.0	6.0	100.0	-
3	Shaikhpura	50	3.02	10.62	5.81	98.0	2.0	100.0	-
4	Rajpuria	50	1.63	12.99	6.08	98.0	2.0	100.0	-
5	Kishorepura	50	2.01	12.73	6.27	94.0	6.0	100.0	-
6	Chudiyawas	82	7.12	17.32	8.38	63.0	29.0	92.0	08
7	Udaipuria	63	8.16	19.56	9.26	71.0	21.0	92.0	08
8	Bagpura	69	6.34	18.88	7.68	58.0	36.0	94.0	06
9	Kheda	56	8.40	21.42	9.18	67.0	26.0	93.0	07
10	Pyariwas	84	9.28	24.18	8.96	69.0	23.0	92.0	08
11	Bagpura (Chhareda)	50	8.0	16.7	10.8	42.0	58.0	100.0	-
12	Kala Raman	50	3.3	20.0	8.5	80.0	20.0	100.0	-
13	Tintoli	50	4.3	11.7	8.2	90.0	10.0	100.0	-
14	Manpuriya	54	2.4	15.0	7.0	89.0	11.0	100.0	-

oilseeds and pulses which require high amount of sulphur.

Direct effect on clusterbean

Addition of sulphur had positive and significant effect on seed and straw yields of clusterbean (Table 2). As compared to control, application of increasing levels of sulphur up to 45 kg S/ha significantly increased seed yield by 67.9 per cent and straw yield by 59.0 per cent, respectively. This may be attributed to early flowering and greater pod setting. Singh *et al.* (2005) also reported similar findings. The overall agronomic efficiency in terms of yield

Table 2. Response of clusterbean to sulphur fertilization (pooled over 3 years)

Sulphur (kg/ha)	Seed levels (kg/ha)	Straw yield (kg/ha)	% response yield (Seed yield)	AE (kg kg^{-1})	AR (%)	PE (kg kg^{-1})	S uptake (kg/ha)		Value: cost ratio
							Seed	Straw	
0	677	1040					1.88	1.42	
15	914	1280	35.0	15.8	11.5	137.0	2.78	2.25	36.5
30	1057	1522	56.1	12.7	14.0	90.5	3.94	3.57	29.3
45	1137	1654	67.9	10.2	12.8	79.7	4.65	4.42	23.7
S.Em ±	22	33					0.09	0.09	
CD (P=0.05)	64	95					0.25	0.26	

AE: Agronomic efficiency; AR: Apparent recovery: PE; Physiological efficiency increase was maximum under low level of sulphur i.e. 15 kg S/ha and thereafter, reduction in agronomic efficiency at higher levels was observed. Agronomic efficiency at S levels of 15, 30 and 45 kg/ ha was 15.8, 12.7 and 10.2 kg/kg S, respectively. Singh *et a*l. (2000) also reported similar results. The value: cost ratio also decreased with increasing levels of sulphur up to 45 kg S/ha and revealed that sulphur application was found to be more remunerative. The highest value: cost ratio was recorded at 15 kg S/ha (36.5).

Removal of sulphur by clusterbean (seed and straw) increased significantly with each increment in sulphur level and the maximum uptake was recorded at 45 kg S/ha (4.65 kg by seed and 4.42 kg by straw). Singh and Mann (2007) also reported similar findings. When judged S recovery, it was higher at S level of 30 kg/ha (14.0 %) and thereafter decreased at the highest level of S application (12.8 %). Physiological efficiency measured in terms of kg/kg uptake showed decreasing trend with each higher level of sulphur application and maximum physiological efficiency was recorded at 15 kg S/ha (137.0 kg/ kg).

Residual effect on wheat

There was a significant residual effect of sulphur fertilization on grain and straw yields of succeeding wheat (Table 3). Application of sulphur up to 45 kg/ha significantly improved grain yield by 34.7 per cent and straw yield by 33.2 per cent over the control. It was interesting to note that the improvement due to residual effect of S was continuous with an increasing level of S application to the preceding crop. This may be attributed to enrichment of soil with sulphur, resulting in its more uptake. The results are in close conformity with the findings of Sharma and Singh (2005).

Productivity of cropping system

Productivity of clusterbean -wheat cropping system in terms of yield gain improved with the application of sulphur up to 45 kg/ha (Table 3). The per cent response to 15, 30 and 45 kg S/ha was worked out to be 12.3, 28.7 and 40.2 over

Table 3. Response of clusterbean - wheat cropping system to sulphur fertilization (pooled over 3 years)

Sulphur levels (kg/ha)	Wheat yield (kg/ha)		Clusterbean -wheat system							
	Grain	Straw	Yield gain	% response	AE (kg kg^{-1})	AR (%)	PE (kg kg^{-1})	S uptake		Value: cost ratio
								Grain	Straw	
0	3378	4430						7.81	7.29	
15	3642	4791	501	12.3	33.4	26.3	127.2	9.83	9.22	56.6
30	4163	5432	1165	28.7	38.8	34.2	113.7	12.65	12.70	60.0
45	4549	5899	1631	40.2	36.2	34.7	104.6	15.48	15.22	53.8
S.Em ±	70	102								
CD (P=0.05)	200	293								

AE: Agronomic efficiency; AR: Apparent recovery: PE; Physiological efficiency the control, respectively. Agronomic efficiency increased up to 30 kg S/ha and thereafter declined with further increase in S level. Agronomic efficiency was 33.4, 38.8 and 36.2 kg/kg S with the application of 15, 30 and 45 kg S/ha applied to cluster bean, respectively. Increasing level of sulphur up to 30 kg /ha resulted in increase in value: cost ratio and thereafter, it declined. It showed that there are possibilities of getting good returns from added S.

Removal of sulphur by clusterbean - wheat cropping system increased with each increment in sulphur level and the maximum uptake was recorded at 45 kg S/ha (15.48 kg by seed/grain and 15.22 kg by straw). Apparent sulphur recovery increased and physiological efficiency decreased with the increased level of sulphur. Maximum apparent sulphur recovery was recorded at 45 kg S/ha (34.7 %) while physiological efficiency was maximum at 15 kg S/ha (127.2 kg/ kg S uptake).

Available sulphur status after harvest

A decrease in soil sulphur status was noticed after harvest of clusterbean – wheat cropping system under the control as well as under treatment of lower level of sulphur i.e. 15 kg S/ha as compared to initial sulphur status (Table 4).Whereas, the sulphur application at higher rates i.e. 30 and 45 kg S/ha improved the soil available sulphur status. After 3 years of continuous cropping on the fixed site, the status of available S exhausted by 46.9 and 15.6 per cent under the control and 15 kg S/ ha whereas it was improved by 49.2 and 94.5 per cent at 30 and 45 kg S/ha, respectively

Table 4. Effect of cropping on available sulphur status of soil (kg/ha) (Pooled over 3 years)

Sulphur levels (kg/ha)	Available sulphur (kg/ha)	Per cent change from initial status
0	6.8	- 46.9
15	10.8	- 15.6
30	19.1	49.2
45	24.9	94.5
Initial status	12.8	

Thus it can be concluded that application of sulphur @ 45 kg S/ha through single super phosphate in clusterbean was effective in increasing the productivity of clusterbean -wheat cropping system in semi arid tract of Rajasthan.

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COMPARATIVE STUDY OF GRANULAR VS PRILLED UREA IN RICE-WHEAT CROPPING SYSTEM

B.R. Gupta, Ashok Kumar, T.P. Tiwari and D.D. Tiwari

Department of Soil Science and Agricultural Chemistry, C.S. Azad University of Agriculture and Technology, Kanpur-208002

Abstract

Field experiments were conducted at Fertilizer Research Station, Uttaripura of the university during 2005-06 and 2006-07 in rice (Pant 12)-wheat (K-9644) cropping system to compare the effect of granular urea (GU) vis-a-vis prilled urea (PU) at different levels of recommended N. Results indicated that application of nitrogen through granular urea was superior to prilled urea. The rice yield increased from 118 to 193 kgha^{-1} and wheat yield 105-166 kgha^{-1} and net return was higher Rs. 1033 ha^{-1} in rice and Rs. 1523 ha^{-1} in wheat with granular urea as compared to prilled urea. Significant increase in yield of rice and wheat was recorded at 125% RD over recommended 50% RD of nitrogen applied either through GU or PU.

Key words: Prilled, granular urea, NUE.

Nitrogen use efficiency in low land rice is low to the extent of 30-40% only (Mahapatra *et al.* 1991). Such low recovery of added nitrogen is attributed to leaching, dentrification, volatilization, runoff and immobilization. The most commonly source of N in the country is urea. Split application of urea is generally recommended for higher efficiency. Granular urea is a modified form of urea with bigger pillet size manufactured by IFFCO. In the present study, comparative efficiency of granular urea (GU) vs prilled urea (PU) was studied under field condition in rice wheat sequence with the objective to evaluate granular urea in comparison to prilled urea in terms of crop yield and the nitrogen use efficiency as affected by treatments.

Materials and Methods

On station trial was conducted at fertilizer research station, Uttaripura of the university during 2005-06 and 2006-07 in rice (Pant 12)-wheat (K 9644) system. Experimental soil was alkaline in reaction (pH 8.1) with EC 0.25 dsm^{-1}, available P 11.1 kgha^{-1}, available K 180 kgha^{-1}, O.C. 0.38%, available N 190 kgha^{-1} and Zn 0.74 mgkg^{-1} soil. Two sources of Nitrogen viz (1) Granular Urea (GU) (2) Prilled Urea (PU) were used with four level of nitrogen viz. (1) 50% RD (2) 75% RD (3) 100% RD (4) 125% of recommended dose (RD) of nitrogen. The recommended N for both rice and wheat was 150 kgha^{-1}. Basal application of 60kg P_2O_5 and 60 kg K_2O in rice and 60 kg P_2O_5 and 40 kg K_2O ha^{-1} in wheat was done. Treatments were replicated four times in factorial RBD design.

After harvesting of crops grain and straw yield were recorded. Nitrogen in plant material was estimated by Micro Kjeldahl method (Jackson 1973) and uptake was calculated by the equation as nitrogen uptake

$$\text{kg ha}^{-1} = \frac{\text{N\% content x yield kg ha}^{-1}}{100}$$

Results and Discussion

Rice yield : A significant linear increase in grain yield of rice was recorded upto 125% RD of nitrogen applied either through PU or GU. Out of the two sources of nitrogen used the application through GU gave bit higher grain yield of rice, varying from 75 to 225 kgha^{-1} over prilled urea application. However statistically both the sources were comparable. However the increase could not reach the level of significance. Net return in GU treatment over PU ranged from Rs. 370 to 1073 with mean value of Rs. 625 ha^{-1} during Ist year and Rs. 1039 to 1631 with mean return of Rs. 1391 ha^{-1} during IInd year [Tables 1 (a) and 1 (b)]. Interaction between N levels on sources was not significantly superior of large size urea granular over prilled urea has also been reported by Singh and Singh 1989.

Wheat yield : Similar to rice grain yield of wheat increased with increasing level of nitrogen applied either through granular urea or prilled urea GU

Table 1 (a). Effect of nitrogen through prilled urea (PU) and granular urea (GU) on the rice and wheat yield (kgha^{-1}) and net return (Rsha^{-1}) during 2005-06

Levels of nitrogen	Rice (2005)				Wheat (2005-06)			
	Grain yield		Mean	Net return GU over PU Rsha^{-1}	Grain yield		Mean	Net return GU over PU Rsha^{-1}
	PU	GU			PU	GU		
T_1 50% RD	3450	3580	3512	828.0	2975	3075	3025	725
T_2 75% RD	4100	4280	4187	1073.0	3225	3400	3312	1350
T_3 100% RD	4800	4850	4825	370.0	3475	3650	5000	1482
T_4 125% RD	5175	5250	5212	432.0	3550	3700	3625	1325
Mean	4381	4487	-	675.0	3306	3456	-	1221
CD 5%	**N levels**	**Source**	**N x S**		**N levels**	**Source**	**N x S**	
	356	NS	NS		210	NS	NS	

Table 1 (b). Effect of nitrogen through prilled urea (PU) and granular urea (GU) on the rice and wheat yield (kgha^{-1}) and net return (Rsha^{-1}) during 2006-07

Levels of nitrogen	Rice (2006)				Wheat (2006-07)			
	Grain yield		Mean	Net return GU over PU Rsha^{-1}	Grain yield		Mean	Net return GU over PU Rsha^{-1}
	PU	GU			PU	GU		
T_1 50% RD	3260	3420	3340	1039	3200	3310	3255	925
T_2 75% RD	3925	4180	4052	1631	3580	3710	3645	1579
T_3 100% RD	4630	4850	4750	1561	3800	3990	3895	2591
T_4 125% RD	4980	5180	5080	1330	3910	4066	3988	2213
Mean	4198	4407	-	1391	3622	3769	-	1825
CD 5%	**N levels**	**Source**	**N x S**		**N levels**	**Source**	**N x S**	
	338	NS	NS		214.5	NS	NS	

appeared superior over PU increasing the grain yield from 100 kg to 175 kgha^{-1} and 110 kg to 156 kgha^{-1} during Ist and IInd year respectively but the increase was not significant. The interaction between nitrogen level and source of nitrogen was also non significant. Net return (Rs.ha^{-1}) in GU treatment over PU ranged from Rs. 725 to Rs. 1482 with mean return Rs. 1221 and Rs. 925 to Rs. 2591 with mean return of Rs. 1825 ha^{-1} during Ist and IInd year, respectively [Table 1(a) and 1(b)] similar result was also reported by Mahapatra and Sharma 1989.

Nitrogen uptake : The N uptake corresponding to yield of rice significantly increased with increasing levels of nitrogen either through PU or GU. Uptake in grain ranged from 44 to 76 kgha^{-1} and 42 to 78 kgha^{-1} during Ist and IInd year respecting as affected by nitrogen doses on mean basis. In case of wheat N uptake significantly affected by nitrogen doses ranged from 47 to 67 kgha^{-1} and 53 kg to 77 kgha^{-1} in grain

Table 2 (a). Effect of nitrogen through prilled urea (PU) and granular urea (GU) on nitrogen uptake (kgha^{-1}) rice and wheat crop during 2005-06

Levels of nitrogen	N uptake Rice (2005)			N uptake Wheat (2005-06)		
	Grain yield		Mean	Grain yield		Mean
	PU	GU		PU	GU	
T_1 50% RD	43.47	45.47	44.47	46.11	48.15	47.13
T_2 75% RD	56.78	59.41	58.09	54.24	57.39	55.81
T_3 100% RD	60.64	70.00	69.32	61.85	65.33	63.59
T_4 125% RD	76.18	77.60	76.89	65.82	68.82	67.32
Mean	61.26	63.12	-	57.00	59.92	-
CD 5%	**N levels**	**Source**	**N x S**	**N levels**	**Source**	**N x S**
	4.85	NS	NS	3.75	NS	NS

Table 2 (b). Effect of nitrogen through prilled urea (PU) and granular urea (GU) on nitrogen uptake (kgha^{-1}) rice and wheat crop during 2006-07

Levels of nitrogen	N uptake Rice (2006)			N uptake Wheat (2006-07)		
	Grain yield		Mean	Grain yield		Mean
	PU	GU		PU	GU	
T_1 50% RD	41.59	44.04	42.81	51.84	54.01	52.92
T_2 75% RD	54.67	58.93	56.80	60.50	63.00	61.75
T_3 100% RD	69.45	73.13	71.29	67.94	71.82	36.77
T_4 125% RD	76.19	80.03	78.11	72.33	75.83	74.08
Mean	60.47	64.03	-	63.15	66.16	-
CD 5%	**N levels**	**Source**	**N x S**	**N levels**	**Source**	**N x S**
	5.10	NS	NS	3.96	NS	NS

during I[st] and II[nd] year respectively at different doses of nitrogen [Table 2(a) and 2(b)]. The significant increase in uptake might be due to higher yield obtained with the application of higher dose of nitrogen. The similar result has been reported by Pal 1996.

Internal nitrogen use efficiency : increase in internal nitrogen use efficiency in rice due to granular urea over prilled urea varied from 1.68 to 6.0% and 4.49 to 6.47% with mean value of 3.29 and 5.88% during I[st] and II[nd] year respectively. The higher nitrogen use efficiency was observed at lower doses of nitrogen applied. Similar trend was noted in case of wheat efficiency of nitrogen interms of increased nitrogen uptake which tended to increase with use of granular urea over prilled urea. The average nitrogen use efficiency increased by 5.16% with granular urea ranging from 3.59% to 6.16% during I[st] year and 5.76% by ranging from 3.16% to 8.32% during II[nd] year in contrast to rice there was no considerable variation in nitrogen use efficiency as affected by N doses [Table 3(a) and 3(b)]. The increase efficiency of granular urea may be due to reduced volatilization of Ammonia and reduced nitrification (Singh and Sivay 2003) and Flinn *et al.* 2005.

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Table 3 (a). Nitrogen use efficiency affected by sources of nitrogen (PU and GU) in rice and wheat during 2005-06

Levels of nitrogen	Rice (2005)			Wheat (2005-06)		
	Internal N use efficiency		Mean	Internal N use efficiency		Mean
	PU	GU		PU	GU	
T_1 50% RD	65.35	69.27	3.92	66.29	68.67	2.38
T_2 75% RD	90.16	93.90	3.75	81.68	86.04	4.36
T_3 100% RD	112.60	115.80	3.20	95.02	100.87	5.85
T_4 125% RD	126.38	128.51	2.13	103.23	108.52	5.29
Mean	98.62	101.87	3.25	86.55	91.02	4.47

Table 3 (b). Nitrogen use efficiency affected by sources of nitrogen (PU and GU) in rice and wheat during 2006-07

Levels of nitrogen	Rice (2006)			Wheat (2006-07)		
	Internal N use efficiency		Mean	Internal N use efficiency		Mean
	PU	GU		PU	GU	
T_1 50% RD	61.82	65.82	4.00	73.83	76.16	2.33
T_2 75% RD	85.08	90.46	5.38	89.75	93.87	4.12
T_3 100% RD	111.06	118.02	6.96	103.06	110.25	7.19
T_4 125% RD	123.9	129.47	5.57	108.73	117.78	9.05
Mean	95.46	100.94	5.48	93.84	99.51	5.67

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STUDIES ON EFFICIENCY OF SEED TREATMENTS AND SOWING METHODS ON YIELD OF LATE SOWN WHEAT (*TRITICUM AESTIVUM* L.) BASED CROPPING SYSTEM

S. KUMAR, O.P. SINGH AND D.D. YADAV

Department of Agronomy, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur-208002

ABSTRACT

A field experiment was conducted during *rabi* season of 2005-06 to work out the sowing method and seed treatment for late sown wheat (*Triticum aestivum* L.emend . Fiori & Paol.). Significantly yield attribute character, staw yield, grain yield and benifit:cost ratio were achieved in sprouted seed followed by water soaked seed and seed treated with $ZnSo_4$ over dry seed. Cross sowing method proved significantly higher in respect of yield attribute character and grain yield of wheat. Cross sowing produced higher grain yield and benefit: cost ratio of wheat than broad casting and line sowing, respectively.

Key word: Late sowing wheat, Sowing method, Seed Treatment, Yield

India ranks second next to china in global wheat production Generally sowing of wheat gets delayed due to late harvesting of Cotton, toria, rice or unprecedented incessant rains . Poor and late germination, unsatisfactory growth, low tillering, more unproductive tillers and forced maturity are mainly responsible for low yield level of late sown wheat (Khan and Chatterjee 1981). Lack of optimum plant population per unit area faced in sowing of late- sown wheat (*Triticum aestivum* L.emend .Fiori & Paol.) because recommened row spacing limited. Under such condition there is a need to explore possibilities of increasing plant population per unit area for obtaining higher yields. Gogoi and Kalita (1995) recorded that cross-sowing increases the grain yield of wheat under late –sown condition. Certain measure has been suggested to check the yield reduction of delayed wheat, in which most recent is soaking of seed with various solutions before sowing, soaking of seed in water, Sprouted wheat seed and seed treated with zinc sulphate. Hence the present investigation was conducted to evaluate the suitable sowing method and seed treatment for late sown wheat

A field experimental was conduced in field at students' instructional farm of Chandra Shakher Azad University of Agriculture and Technology, Kanpur, during *rabi* season of 2005-06. Three sowing methods (broadcasting , 20cm line sowing and 20cm cross-sowing) and 4 seed treatments (dry seed , water soaked, sprouted and treated with $ZnSo_4$) were tested in randomized block design with 3 replications. The soil was Sandy loam ,having pH 7.8 , organic carbon 0.54%, 0.051% total Nitrogen, 23.4 kg/ha available P_2O_5 and 250 kg/ha available K_2O .Wheat cultivar K – 9423 (Unnat Halna) was sown on 27, December during 2005 , adopting all recommended package of practices. The crop was irrigated five times and weeding was done once only. There was no need to adopt plant protection

*Present address: Satendra Kumar, Research Scholar, G.B. Pant University of Agri. & Tech. Pantnagar, Uttrakhand-263145

measure and the crop was harvested on 6 May, 2006.

SEED TREATMENT

Sprouted seed significantly higher grain yield than dry seed whereas it was at par with water soaked seed and seed treated with $ZnSO_4$. Biological yield and straw yield were significantly higher in sprouted seed than dry seed and seed treated with ZnSO4 while at par with water soaked seed. Number of spikelet/ ear, length of ear, number of grain/ear and grain weight/ear were significantly superior in sprouted seed than dry seed and other treated seed. The lowest value was recorded in dry seed. However, sowing of sprouted seed which have already sprouted before sowing and established earlier than dry seed and other soaked seed. The findings confirm the results of Dayanand and Agrawal (1977), Mahajan *et al* (1991). Sprouted seed gave significantly higher spikes per m^2 than dry seed, seed treated with ZnSO4 while at par with water soaked seed. Benefit: cost ratio was highest in sprouted seed, followed by water soaked seed , $ZnSo_4$ treated seed and dry seed.

SOWING METHOD

Grain yield and straw yield were significantly higher in cross- sowing than other sowing methods. The line sowing was next best, giving significantly higher straw and grain yield than broadcasting sowing. Cross sowing gave significantly higher biological yield than broadcasting while at par with the line sowing method. The yield contributing characters like number of spikes per ear, length of ear, number of grains per ear, grain weight per ear and spikes per m^2 were significantly higher in cross sowing than line sowing and broadcasting.. All the yield contributing characters increased due to better growth and development of the crop, resulting better yield contributing characters in cross sowing because uneven distribution and

Table 1. Grain, biological, straw yields, yield attributes character and benefit: cost ratio as affected by seed treatments and sowing methods.

Treatment	Grain Yield (q/ha)	Straw Yield (q/ha)	Biological Yield (q/ha)	Spiklets/ ear (No.)	Spike length (cm)	Grains/ spike	Grain weight per ear	Benefit: cost ratio
Seed treatment								
Dry seed	36.76	52.08	88.84	13.66	6.83	35.27	1.14	1.28
Water soaked	44.45	52.85	97.27	15.25	7.47	38.44	1.40	1.63
Sprouted seed	44.56	54.01	98.58	16.06	8.23	41.55	1.58	1.65
$ZnSo_4$ Treated	41.85	50.54	92.39	14.51	7.37	36.32	1.33	1.49
$S_{E.}m$	2.25	1.03	1.43	0.15	0.08	0.76	0.04	
CD at 5%	4.67	2.15	2.97	0.31	0.16	1.15	0.08	
Sowing method								
Broadcasting	39.76	53.13	92.90	14.32	7.06	35.17	1.20	1.69
Line sowing (20 cm)	40.41	53.69	94.10	14.88	7.62	37.07	1.38	1.48
Cross sowing (20 x 20 cm)	45.54	50.29	95.81	15.40	7.75	41.44	1.50	1.58
$S_{E.}m$	1.95	0.90	1.24	0.13	0.06	0.67	0.03	
CD at 5%	4.04	1.86	2.57	0.27	0.14	1.38	0.07	

improper depth of seeds in broadcasting sowing method caused significantly reduction in plant population per unit area. Similar results were also reported by Singh *et al.* (1993), Jat and Singh (2004) and Kumpawat (1998). Benefit: cost ratio was highest in cross-sowing, followed by line sowing and broadcasting sowing method.

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INFLUENCE OF INTEGRATED NUTRIENT MANAGEMENT ON PRODUCTIVITY AND SOIL FERTILITY IN PEARLMILLET-WHEAT CROP SEQUENCE

R.M. Solanki, B.K. Sagarka and V.D. Khanpara

Department of Agronomy, Junagadh Agricultural University, Junagadh-362 001 (Gujarat)

Abstract

Field experiment was conducted at Junagadh in *kharif* and rabi season of 2000-01 to 2006-07 on medium black soil to study the effect of organic and inorganic sources of nitrogen on pearlmillet-wheat crop sequence. The six year pooled results revealed that the application of nitrogen to individual crop as per soil test value through inorganic fertilizer produced significantly higher grain yield (1586 and 4033 kg ha-1) and straw yield (10325 and 4945 kg ha-1) of pearlmillet and wheat, respectively as well as gross (Rs. 58409 ha-1) and net realization (Rs. 34223 ha-1). Application of RDN to pearlmillet and wheat crops in combination of organic manures and inorganic fertilizers failed to improve available soil nutrient status after harvest of each crop, except available K2O observed significantly maximum after harvest of pearlmillet and wheat and organic carbon after harvest of wheat when each crops were fertilized with 100% RDN through FYM. NPK uptake by grain and straw were also observed higher when RDN was applied as per soil test value except, K uptake by pearlmillet grain was maximum when 75% RDN of pearlmillet applied through inorganic fertilizer and 25% RDN through FYM and castor cake and N uptake by pearlmillet straw was significantly higher when 50% RDN of pearlmillet applied through inorganic fertilizer and 50% RDN through FYM and castor cake.

Key words: Pearlmillet, wheat, INM, RDN, FYM, crop sequence

Pearlmillet-wheat sequential cropping is becoming popular in double cropping system under irrigated conditions in arid and semi arid tracts of western and north-western India. This system is fairly exhaustive and a crop giving 2.9 tones/ha of pearlmillet and 4.2 tonnes/ha of wheat may remove 238, 54 and 131 kg/ha N, P and K, respectively (Hegde *et al.*, 1992). Long term studies, being carried out at several locations in different cropping systems indicated that application of all the needed nutrients through chemical fertilizers has deleterious effect on soil fertility leading to unsustainable yields (Hegde, 1992, Nanbiar *et al.*, 1992). Sufficient information is available on response of pearlmillet and wheat crop to fertilizer application in the sole crops. However, limited information is available on integrated nutrient management on pearlmillet-wheat cropping system. It is being realized that system based research could be more advantageous for optimizing the use of different sources of plant nutrients. Also due to escalation of fertilizer prices, the integrated nutrient supply approach would be more remunerative for getting higher returns with considerable fertilizer economy and better soil health. Keeping in view these facts, the present investigation was carried out to study the effect of organic manures in combination with chemical fertilizers on yields and nutrient uptake by pearlmillet-wheat crops in sequence of the region.

Materials and Methods

Field trials were conducted during *Kharif* and rabi from 2000-01 to 2006-07 at Instructional Farm, Junagadh Agricultural University, Junagadh

(Gujarat). The soil of the fixed experimental site was medium black calcareous clayey containing 0.80% organic carbon, 212.0 kg ha^{-1} available N, 48.5 kg ha^{-1} available P_2O_5 , 242.0 kg ha^{-1} available K_2O, 10.3 ppm S and pH 7.9. The ten treatments consisted of combination of organic sources of nitrogen and chemical fertilizers in different proportion *viz.*, F_1- FYM (100% N), F_2- FYM (75% N) + Castor cake (25% N), F_3- FYM (50% N) + Castor cake (50% N), F_4- FYM (25% N) + Castor cake (75% N), F_5- Castor cake (100% N), F_6- Organic fertilizer (25% N, of which 50% N each from FYM and castor cake) + inorganic fertilizers (75% N), F_7- Organic fertilizer (50% N, of which 50% N each from FYM and castor cake) + inorganic fertilizers (50% N), F_8- Organic fertilizer (75% N, of which 50% N each from FYM and castor cake) + inorganic fertilizers (25% N), F_9- Inorganic fertilizers (100% as per soil test) and F_{10}- Inorganic fertilizers (100% N as per recommendation) tested in randomized block design with four replications. In treatments 1 to 8 N was applied as per recommendation instead of soil test and no P and K were applied. The N content in different organic manures was determined each year and the amount of these organic manures require for substituting a specific amount of N was as per the treatment was calculated. The pearl millet cv. GHB-316 and wheat cv. GW-496 were sown under recommended package of practices. All the organic manures and chemical fertilizers were applied to individual plots in the previously opened furrows at 60 cm for pearlmillet and 22.5 cm for wheat crop as per treatments before sowing the crop and incorporated in soil. Soil samples i.e. before sowing the crop in first year and after harvest of crop every seasons were collected from each plot from 0-15 cm depth and analyzed for O.C., available N, P_2O_5, K_2O and S. The grain and straw samples were analyzed for total N, P, and K uptake by the crops during experimental period. Observations on yield and yield attributes were recorded from each plot and economics were worked out on the basis of current market prices of produce and inputs used. Other cultural operations were carried out as per recommendations made for each crop in the region.

Results and Discussions

Pearlmillet and wheat yields:

Pooled results of 6 years presented in Table-1 revealed that application of chemical fertilizers as per soil test value (T_9) to individual crops resulted in significantly increased in grain (1586 $kgha^{-1}$) of pearlmillet which was comparable with T_5 (i.e. 100% N through castor cake) and T_6 (i.e. 25% N of which 50% N each through FYM and castor cake and 75% N through fertilizer).Significantly higher fodder yield of pearlmillet 10325 $kgha^{-1}$ was produced when crop was fertilized as per soil test value (T_9) and observed statistically at par with T_6 (i.e. 75% N through fertilizer and 25% N through organic manures of which 50% each through FYM and castor cake) and T_7 (i.e. 50% N through fertilizer and 50% N through organic manures of which 50% each through FYM and castor cake). Similarly, significantly maximum grain (4033 $kgha^{-1}$) and straw yields (4945 $kgha^{-1}$) of wheat was recorded when crop was fertilized as per soil test value (Table-1) and found statistically on par with T_8 (i.e. 25% N through fertilizer and 750% N through organic manures of which 50% each through FYM and castor cake). These results are in line of those reported by Hegde (1998), Roshan *et al.* (1995) and Singh *et al.* (1999).

Table 1: Effect of different treatments on yield and economics of pearl millet-wheat crop sequence (Mean of six years)

Treatment	Yield(kg ha^{-1})				Realization(Rs. ha^{-1})			B:C ratio
	Pearl millet		Wheat		Gross	Cost	Net	
	Grain	Fodder	Grain	Straw				
T_1	1293	9286	3795	4013	52832	28560	24272	0.85
T_2	1127	8567	3692	3939	50076	28491	21585	0.76
T_3	1184	8302	3728	4135	50726	29081	21645	0.74
T_4	1371	8250	3685	4043	51658	29342	22316	0.76
T_5	1464	8325	3247	3874	48384	29587	18797	0.64
T_6	1466	9681	3497	4087	51773	24667	26906	1.09
T_7	1370	9627	3646	4215	52417	26113	26304	1.01
T_8	1282	8379	3835	4383	52606	27296	25310	0.93
T_9	1586	10325	4033	4945	58409	24186	34223	1.00
T_{10}	1338	9250	3565	4321	51229	23936	27194	1.14
C.D.(P=0.05)	149	1034	202	411				

Soil fertility:

The pooled results of 6 years furnished in Table-2 indicated that application of recommended dose of nitrogenous fertilizers to pearlmillet and wheat crops in combination of organic manures and fertilizers failed to exert their significant effect on soil nutrient status after harvest of each crop, except available K_2O in soil after harvest of pearlmillet and wheat and organic carbon content after harvest of wheat was observed significantly higher when 100% recommended dose of N was applied through FYM (T_1). The increase in organic carbon content and K_2O with FYM was mainly due to addition of organic matter (Patnaik *et al.*, 1989).

Nutrient uptake:

Six years pooled data presented in Table-3 showed that N, P and K uptake by grain and straw of pearlmillet were significantly affected by various treatments. Significantly higher N (24.56 $kgha^{-1}$) and P (3.19 $kgha^{-1}$) uptake by grain were recorded with the application of fertilizer as per soil test value (T_9) which was comparable with T_4, T_5, T_6, T_7, T_8 and T_{10} for N and T_5, T_6, T_7, T_8 and T_{10} for P. Incase of K uptake the significantly higher K (3.86 $kgha^{-1}$) uptake by pearlmillet grain was observed with the 75% N applied through fertilizers and 25% N of which 50% n each through FYM and castor cake (T_6) and remained statistically at par with T_5, T_7, T_8, T_9 and $T_{10.}$ Significantly higher N uptake of 92.15 $kgha^{-1}$ by pearlmillet fodder was recorded when crop was fertilized with 50% N through fertilizers and 50% N of which 50% N each through FYM and castor cake (T_7) and observed on same bar with T_5, T_6, T_8, T_9 and T_{10}. While significantly higher P (28.59 $kgha^{-1}$) and K (105.93 $kgha^{-1}$) uptake by pearlmillet fodder were recorded when crop was fertilized as per soil test value

Table2: Effect of different treatments on soil nutrient status after harvest of pearlmillet and wheat (Mean of six years)

Treatment	O.C. (%)	Available nutrient after pearl millet (kg ha^{-1})			S (ppm)	O.C. (%)	Available nutrient after wheat (kg ha^{-1})			S (ppm)
		N	P_2O_5	K_2O			N	P_2O_5	K_2O	
T_1	0.84	232.8	65.3	203.4	10.1	0.89	219.3	65.6	196.1	10.6
T_2	0.87	225.4	67.0	199.0	10.9	0.88	219.1	68.3	186.5	14.8
T_3	0.81	226.5	67.5	188.9	11.2	0.83	216.9	70.7	182.8	11.0
T_4	0.79	229.6	67.7	188.0	11.1	0.88	217.0	67.3	175.2	10.7
T_5	0.78	226.3	66.0	176.5	11.1	0.82	212.3	68.3	172.6	10.5
T_6	0.82	230.0	67.9	173.9	10.9	0.84	215.6	68.1	169.8	10.9
T_7	0.80	227.8	69.1	180.1	10.9	0.84	211.8	70.1	170.1	11.1
T_8	0.83	227.2	67.6	183.4	11.4	0.87	214.1	69.4	173.5	11.3
T_9	0.81	227.4	67.2	171.3	11.0	0.81	212.6	70.6	165.0	11.0
T_{10}	0.79	224.6	67.2	164.3	11.5	0.80	214.3	70.5	158.1	11.2
C.D.(P=0.05)	NS	NS	NS	11.42	NS	0.05	NS	NS	7.90	NS

Table 3: Effect of different treatments on uptake (kg ha^{-1}) of N, P and K by Pearl millet-wheat sequence (Six years pooled).

Treatment	Uptake (kg ha^{-1})											
	Pearl millet						Wheat					
	Grain			Fodder			Grain			Straw		
	N	P	K	N	P	K	N	P	K	N	P	K
T_1	18.69	2.56	2.98	73.65	22.06	97.50	55.28	11.23	11.74	22.12	2.05	34.93
T_2	19.26	2.42	2.95	76.99	24.70	92.74	54.31	11.45	11.54	21.27	2.24	34.53
T_3	18.91	2.51	3.03	70.28	23.18	91.26	57.00	11.10	11.55	23.68	1.88	35.61
T_4	22.37	2.72	3.30	77.84	26.26	89.43	58.83	11.48	11.61	22.63	2.12	33.70
T_5	23.94	3.14	3.78	88.75	25.31	93.63	57.58	10.14	11.08	22.20	2.09	29.56
T_6	24.48	3.13	3.86	85.13	28.08	99.51	53.25	10.07	10.62	25.47	2.05	26.84
T_7	23.14	3.07	3.65	92.15	25.65	100.62	58.67	10.37	11.04	24.06	2.00	26.00
T_8	22.79	2.82	3.52	82.09	24.06	96.56	60.19	11.04	11.90	24.93	2.27	31.46
T_9	24.56	3.19	3.81	87.97	28.59	105.93	64.60	11.79	12.44	28.03	3.08	40.14
T_{10}	22.26	2.92	3.62	82.81	22.40	82.65	58.70	10.21	11.05	26.94	2.37	32.36
C.D.(P=0.05)	2.87	0.40	0.54	12.77	4.28	13.26	6.00	1.21	1.02	4.09	0.67	5.50

(T_9) and found statistically at par with T_2, T_4, T_5 and T_7 for P and T_1, T_2, T_5, T_6, T_7 and T_9 for K.

Uptake of N, P and K by grain and straw of wheat was significantly affected by various treatments (Table-3). Significantly higher N (64.60 $kgha^{-1}$), P (11.79 $kgha^{-1}$) and K (12.4 $kgha^{-1}$) uptake by grain and N (28.03 $kgha^{-1}$0 P (3.08 $kgha^{-1}$) and K (40.14 $kgha^{-1}$) uptake by wheat straw were observed when individual crops were fertilized as per soil test value (T_9) and which was at par with T_4, T_7, T_8 and T_{10} for N uptake by grain , T_1, T_2, T_3, T_4 and T_8 for P and K uptake by grain. While in case of straw T_6, T_7, T_8 and T_{10} for N uptake and T_1 and T_3 for K uptake by wheat straw, respectively. Similar results were also reported by Singh *et al.* (1999). it is evident that higher uptake of nutrients by the crops has contributed towards the increase in grain and straw yields.

Economics:

Gross and net realization was also observed numerically maximum when 100% N as per soil test were applied in the form of inorganic fertilizer. More or less similar results were also reported by Patel *et al.* (1995) indicated that significantly higher pearl millet and wheat grain and straw yields were obtained when each crop were fertilized with 75% NPK + 25% NPK through green manuring and which was comparable with 100% RDF through inorganic fertilizers.

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YIELD ESTIMATION IN RICE-RICE CROPPING SYSTEM UNDER LONG-TERM FERTILITY EXPERIMENTS

Anil Kumar*[1], Sanjeev Panwar[2], Vipin Kumar Choudhary[3], Sanat Kumar[4], Pankaj Kumar[5] and Prem Singh[6]

Indian Agricultural Statistics Research Institute, Pusa, ND-110012

Abstract

A long-term experiment was initiated Under All India Co-ordinated Research Project on Cropping Systems during 1978-79 to study the long range effect of a crop sequence with high yielding varieties at graded fertilizer levels on yield stability and soil fertility. Under this broad objective a study had been undertaken to assess the trend and prediction of grain yield based upon best fitted linear/nonlinear models. For all the nineteen treatments, linear/nonlinear models have been fitted to obtain the yield trend as well as yield prediction for three years. This paper presents trend analysis and prediction/ estimation of grain yield over time and discusses the results of applying these models to grain yield values under rice-rice system in LTE.

Key words: Yield trend, cropping systems, prediction, Linear / Non linear models.

Agriculture is the backbone of India's economy, providing direct employment to about 67% of the working people in the country. It forms the basis of many premier industries of India, including the textile, jute, and sugar industries. Agriculture contributes about 29% to GDP; one-fourth of India's exports are agricultural products.

Rice is the staple food of 65% of the total population in India. It constitutes about 52% of the total food grain production and 55% of total cereal production. Food grains consist of cereals such as rice, wheat, sorghum, pearl millet, and maize as well as pulses.

Rough rice production reached 134 million t in 2000 from 112 million t in 1990, growing at 1.9% annually. The growth rate has slowed down significantly from 3.4% per year during the 1980s, mainly from the sluggish performance in the progressive states such as Punjab, Andhra Pradesh, Tamil Nadu, and Haryana, as many districts in these states are approaching the economically optimum yield with the available technologies.

The rough rice yield has increased from 2.61 t/ha in 1990 to 3.01 t/ha in 2000, an annual growth of 1.4%. In Punjab and Tamil Nadu, where almost the entire rice land is irrigated, yield has reached 5.26 t/ha and 5.38 t/ha (1998), respectively. Yield fluctuates widely in Bihar and Orissa, states that suffer from drought and floods often in the same year, making rice cultivation a highly risky economic activity.

Long-term experiments are those experiments which are continued on the same set of experimental units over a sequence of years with preplanned

Corresponding author: E-mail: akumar@iasri.res.in; [1]Senior Scientist, [2]Scientist (SS), Indian Council of Agricultural Research, Krishi Bhawan, ND-110014; [3]Scientist (SS), Project Directorate for Farming Systems Research, Modipuram, Meerut, 250110; [4]Research Fellow, Central Potato Research Stations, Modipuram, Meerut, 250110; [5]Research fellow, Indian Agricultural Statistics Research Institute, Pusa, ND-110012; [6]Principal Scientist, PDFSR, Modipuram, Meerut, U.P.-250 110.

sequence of treatments or crops or both. These are mainly carried out to study the long-term effects of given treatments and crops on soil fertility and on economic returns. Long-term experiments may be with seasonal crops, annual crop sequences, perennial crops, etc. The long-term fertilizer experiments, long-term rotational experiments, etc. fall under the category of long-term experiments with seasonal crops or annual crop sequences. These experiments provide the estimates of effect of continuous application of treatments over the soil productivity and fertility. In long-term experiments changes over time are the primary performance index even though the average performance over years (time) remains as an important measure of productivity. The change over time in either crop productivity or environmental tracts or both is a critical parameter, hence an increasing productivity trend is an important feature of a desirable technology. In addition though the initial productivity may be high but there may be built up of pests or depletion of soil nutrients resulting from continuous application of same treatment or treatment combinations with the prearranged technology. Therefore, long-term experiments provide useful information for sustainability of crop yields as well as management of soil fertility.

Long term experiments (LTE) provide these opportunities. Trends over time in annual crop yields potentially provide measures of the likely long-term sustainability of cropping systems. However, where large annual variability in the growth environment is responsible for most of the large year to year yield differences, (M.J. Jones *et al.*,) appropriate analytical techniques must be developed to distinguish real long-term trends from the 'background noise'.

Material and Methods

Under All India Co-ordinated Research Project on Cropping Systems an experiment "Long range effect of continuous cropping and manuring on soil fertility and yield stability" was initiated during 1978 with the objective to study the long range effect of a crop sequence with high yielding varieties at graded fertilizer levels on yield stability and soil fertility. Being a compulsory experiment this was conducted at all the cropping systems research centres with the major prevailing cereal based cropping systems like rice-rice, rice-wheat, maize-wheat, sorghum-wheat and pearlmillet - wheat.

Rice-rice sequence at Karmana centre was selected for the study. Eighteen fertility combinations, comprising three levels of N (40, 80 and120 kg/ ha) and P (0, 40 and 80 kg / ha) and two levels of K (0 and 40 kg / ha) were evaluated in a 3^2 x 2 partially confounded factorial design in three replications with one control ($N_0P_0K_0$) in each replication.

In these experiments same sequence is followed over the years. Nineteen treatments comprising different combinations of fertilizer doses are the treatments in this fixed rice-rice crop rotation and treatment effects are compared in this study.

Different models were fitted using the curve expert package to calculate the missing yield. Best fitted model was taken to interpolate the missing value and also to predict the yield for to three years after the completion of the experiment. Homogeneity of variance of each year was tested using the Bartlett's test. Whenever the variances were found homogeneous, pooled analysis was carried out to study the overall variability in treatment responses for each season.

Grain yield for rice – rice cropping system for a period from 1978 to 2003 has been analysed using curve expert package. Different linear/non-linear models viz. 3rd degree polynomial fit, MMF, logistic, linear fit, quadratic fit, rational function, exponential fit, etc. have been fitted to all the 19 treatments.

Since data for the year 1980 for both kharif (maize) and rabi (wheat) seasons were missing, best-fitted models for each treatment were used to interpolate the missing yield. Grain yield for further three years i.e. 2004, 2005 and 2006 to all the nineteen treatments were also obtained by using best-fitted models.

Following linear/nonlinear models have been fitted to see the trends and yield prediction of the grain.

1. Linear Models

In the present study, we have applied linear regression approach to fit the straight line (first order response curve) and parabola (second order response curve). Henceforth, we shall call the first order and second order response curves as linear and quadratic polynomials. These are described is as follows:

(a) Linear Polynomial (First order response curve)

A linear polynomial is the equation of a straight line. By its nature, it is best suited to data that is expected to change by the same absolute amount in each time period. The model is represented by the equation

$$Y_t = a + bt + e_t$$

where a is the value of Y_t at time t=0, b is the rate of increase in Y_t for a unit change in time and e_t is the error term.

(b) Quadratic Polynomial (Second degree response curve)

Quadratic function is used to model a series of data, which “takes off” or dampen over time. It is represented by the following equation

$$Y_t = a + bt + ct^2 + e_t$$

where a is the initial value of Y_t, b has same meaning as in linear polynomial and c is the rate of take off or dampening and e_t is the error term.

2. Non-linear growth models

In this study, we give the various non-linear growth models fitted for studying the behaviour of soil status over years in long-term fertilizer experiments.

(a) Exponential Model

This model is used when the data series exhibits compound rate of growth in negative direction over time. This is a nonlinear model, but it can be converted to a form, which is linear in parameter, by logarithmic transformation. Such a model is known as *intrinsically linear model*. In this study, the non-linear form of the model has been fitted. The model can be represented by

$$Y_t = ae^{-bt} + e_t$$

where Y_t is of similar meaning as given earlier, a (>0) is the value of Y_t at time t=0 and b is the exponential rate of decay over time and is the error term.

(b) Logistic model

If Y_t denotes the variable under study like N, P, K or Organic carbon status of soil at time t. Also, let a (>0) denote intrinsic growth rate and c is the maximum N, P, K or OC status of soil. Then this model is represented by

$$Y_t = \frac{c}{1 + a\ exp\ (-bt)}\, e_t$$

where $b = \frac{c - Y_0}{Y_0}$ and Y_0 is the value of Y_t at t=0. Logistic curve is a symmetric sigmoid (S-shaped) curve and is the error term. The point of inflexion is at

$$\left\{\left(\frac{1}{a}\right) ln \left[\frac{(c - Y_0)}{Y_0}\right], \frac{c}{2}\right\}$$

Logistic model is also known as internal influence model.

(c) Gompertz model

Gompertz model is represented by

$$Y_t = a\ exp\ [-b\ exp\ (-ct)] + e_t$$

where symbols have same meaning as in logistic model. This is also sigmoid growth model. But the difference with logistic model is that it is not symmetric. The point of inflexion is at

$$\left\{\left(\frac{1}{a}\right) ln\ (b), \frac{c}{e}\right\}$$

Gompertz model is also known as external influence model.

(d) Monomolecular model

This model describes the progress of a growth situation in which it is believed that the rate of growth at a particular time t is directly proportional to the amount of growth yet to be achieved. This model is represented by

$$Y_t = c - (c - a)\ exp\ (-bt) + e_t$$

where symbols have their usual meaning as in logistic model. But there is no point of inflexion.

Results and Discussion

Yield trend for rice – rice cropping systems for a period from 1978 to 2002 has been analyzed using curve expert package. Different non-linear models like 3rd degree polynomial fit, MMF, logistic, linear fit, rational function, exponential fit, etc. have been fitted to all the 19 fertility treatments. Analysis revealed that in kharif rice under balanced fertility management practices yield trend was slightly downward from 1979-83 to 1994-98 after that it was an upward direction and in rabi seson down trend was observed.

In Kharif (rice), under balanced fertility management practices, yield for years 2004, 2005 and 2006 were predicted by 3rd degree polynomial fit model as 59.28 Q/ha, 67.63 Q/ha and 77.61 Q/ha (Table-1) respectively and in rabi (rice), yield for years 2003, 2004 and 2005 were predicted by quadratic fit model as 22.93 Q/ha, 20.89 Q/ha and 18.68 Q/ha respectively (Table-1). Whereas 3rd degree polynomial fit model predicted for years 2003, 2004 and 2005 as 23.27 Q/ha, 21.39 Q/ha and 19.37 Q/ha respectively (Table-1).

It can be concluded that quadratic, and 3rd degree polynomial fit models can serve as best fitted models for predicting yield under long-term fertility experiments.

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PATTERN OF NITROGEN UPTAKE, YIELD AND QUALITY OF MUSTARD *(BRASSICA JUNCEA L.)* IN RELATION TO CROPPING SEQUENCES AND NITROGEN FERTILIZATION

VINOD KUMAR*, ARVIND KUMAR AND R.P. SINGH

Sardar Vallabh Bhai Patel University of Agriculture & Technology, Modipuram, Meerut - 250 110 (U.P.)

ABSTRACT

The studies of nitrogen management in mustard based cropping systems were carried out during 1996-97 and 1997-98 in tarai region. Six cropping sequences were taken as main plot and 5 N levels as sub-plot treatment a in split plot design. The Cowpea-Mustard sequence recorded highest N uptake in stem at different stages during both the years. Nitrogen uptake in leaves increased between 30 and 60 days stage but thereafter decreased at 90 days after sowing and was highest in Cowpea-Mustard sequence followed by Dhaincha *(Sesbania aculeata)* Mustard sequence. Maize-Mustard and Soybean-Mustard sequences had lowest nitrogen uptake in leaves as well as in Siliquae during both the years. The total N uptake and nitrogen uptake in stem and siliquae were significantly higher in Cowpea-Mustard sequence. The seed and oil yields were also higher in Cowpea-Mustard and Dhaincha- Mustard sequences.

The nitrogen uptake in stem, leaves and siliquae increased with the increase in nitrogen rates at different stages during both the years. Application of 120 kg N/ha recorded significantly higher seed and oil yields over all the lower nitrogen rates but was at par with 160 kg N/ha. Oil content in seeds was highest at 40 kg N/ha. Instead of keeping the land fallow mustard crop preceded with cowpea and application of 120 kg N/ha increased the production of mustard.

Key words: Cropping system, N fertilization, uptake, mustard.

Mustard *(Brassica juncea L.)* is prominently grown as a monocrop or cereal crop in sequence. The inclusion of legumes and green manuring crop in rotation has been reported to improve soil fertility in intensive cropping system and thereby sustaining the productivity. Tomar and Tiwari (1990) observed maximum net return from Black gram-Mustard and Green gram-Mustard sequences over Fallow-Mustard sequence. The present study was therefore, carried out to assess the effect of legumes on mustard and also to workout the nitrogen requirement of mustard.

MATERIALS AND METHODS

A field experiment was conducted during the winter seasons of 1996-97 and 1997-98 at the Crop Research Centre of the G.B. Pant University of Agriculture and Technology, Pantnagar.

The experiment was laid out in split-plot design with three replications. The main plot treatment consisted of 6 cropping sequences (Maize-Mustard, Soybean-Mustard, Moong-Mustard, Cowpea-Mustard, Dhaincha- Mustard and Fallow-Mustard) and sub-plot treatments consisted of five N levels (0, 40, 80, 120 and 160 kg/ha). Fifty days

*Senior Research Fellow, Department of Soil Science, Sardar Vallabhbhai Patel University of Agriculture & Technology, Modipuram, Meerut - 250 110 (U.P.)

Table 1. Nitrogen content (%) in stem, leaves and siliquae at different stages and maturity as influenced by cropping sequences and nitrogen rates during 1996-97 and 1997-98.

Treatments	30 DAS		60 DAS		90 DAS		Maturity	
	Stem	Leaves	Stem	Leaves	Stem	Leaves	Stem	Reproductive part (seeds)
				1996-97				
Cropping Sequences								
Maize-Mustard	3.04	3.20	1.06	1.18	0.63	0.72	0.42	3.09
Soybean-Mustard	2.95	3.02	0.98	1.07	0.60	0.73	0.37	3.05
Moong-Mustard	3.07	3.02	1.11	1.25	0.65	0.75	0.40	3.14
Cowpea-Mustard	3.20	3.36	1.24	1.36	0.75	0.89	0.55	3.19
Fallow-Mustard	3.11	3.30	1.15	1.30	0.65	0.80	0.50	3.15
Dhaincha-Mustard	3.10	3.34	1.19	1.33	0.70	0.85	0.51	3.18
CD (P=0.5)	0.12	0.26	0.08	0.55	0.04	0.44	0.03	0.10
Nitrogen rates (kg N/ha)								
0	2.87	3.12	0.96	1.15	0.59	0.72	0.36	3.07
40	2.99	2.98	1.06	1.19	0.64	0.74	0.40	3.10
80	3.11	3.23	1.14	1.24	0.66	0.79	0.45	3.13
120	3.20	3.29	1.25	1.31	0.70	0.83	0.50	3.16
160	3.23	3.40	1.23	1.35	0.74	0.86	0.58	3.20
CD (P=0.5)	0.09	0.20	0.07	0.42	0.24	0.21	0.18	0.88
				1997-98				
Cropping Sequences								
Maize-Mustard	2.74	3.20	0.94	1.08	0.61	0.60	0.37	2.86
Soybean-Mustard	2.74	3.30	0.85	1.06	0.57	0.57	0.34	3.02
Moong-Mustard	2.75	3.36	0.96	1.14	0.61	0.62	0.38	3.09
Cowpea-Mustard	2.99	3.38	0.98	1.24	0.71	0.69	0.50	3.15
Fallow-Mustard	2.78	3.02	0.96	1.24	0.62	0.64	0.44	3.11
Dhaincha-Mustard	2.80	3.30	0.97	1.28	0.66	0.69	0.46	3.12
CD (P=0.5)	0.60	0.39	0.30	0.57	0.48	0.29	0.26	NS
Nitrogen rates (kg N/ha)								
0	2.68	2.88	0.85	0.99	0.56	0.57	0.33	3.04
40	2.74	3.17	0.89	1.17	0.60	0.61	0.37	3.07
80	2.80	3.31	0.92	1.20	0.62	0.64	0.42	2.92
120	2.84	3.42	1.00	1.23	0.66	0.67	0.45	3.11
160	2.92	3.52	1.06	1.26	0.69	0.69	0.51	3.16
CD (P=0.5)	0.06	0.53	0.52	0.61	0.24	0.11	0.20	NS

old Dhaincha plants were incorporated into the soil for green manuring. Mustard variety Kranti was sown by using 5kg/ha seed rate at a spacing of 30x15 cm. A uniform basal application of 40 kg P_2O_5 and 20 kg K_2O per ha was made along with 50% N. Remaining quantity of nitrogen was top dressed after first irrigation at 30 days stage. Uniform representative samples were randomly collected from each plot, dried, processed and analyzed by Micro-Kjeldahlj method (Jackson, 1967) to determine the nitrogen content in stem and leaves at 30, 60 and 90 days stages. The uptake of nitrogen was obtained by multiplying the nitrogen content with analyzed with respective dry matter production of various plant parts. Oil content (%) in seeds was analyzed with the help of NMR. The oil yield was calculated after multiplying seed yield with oil content in the seeds

Table 2. Nitrogen uptake (kg/ha) in stem, leaves and siliquae at different stages and maturity as influenced by cropping sequences and nitrogen rates during 1996-97 and 1997-98.

Treatments	30 DAS		60 DAS		90 DAS		Maturity		Total
	Stem	Leaves	Stem	Leaves	Stem	Leaves	Stem	Siliquae	N Uptake
1996-97									
Cropping Sequences									
Maize-Mustard	14.1	10.7	32.9	12.0	25.4	3.1	33.7	51.0	84.7
Soybean-Mustard	12.5	9.9	28.5	11.2	27.7	2.6	2938	52.2	82.1
Moong-Mustard	15.0	12.5	33.2	13.2	39.1	3.4	32.5	56.3	88.9
Cowpea-Mustard	13.1	15.9	37.2	15.9	35.4	4.7	45.2	62.4	107.7
Fallow-Mustard	16.9	12.3	34.8	14.7	32.2	3.8	38.9	58.5	95.5
Dhaincha-Mustard	19.5	14.6	37.2	15.7	30.2	4.4	40.5	60.6	101.2
CD (P=0.5)	0.7	0.3	1.2	0.7	2.4	0.1	2.5	4.2	5.2
Nitrogen rates (kg N/ha)									
0	9.3	8.5	22.4	7.6	21.0	1.7	21.2	29.7	51.0
40	13.4	10.1	26.1	10.7	25.4	2.6	26.5	42.2	68.7
80	15.4	12.5	31.4	13.7	30.6	3.8	36.1	53.3	89.5
120	19.3	15.2	40.4	17.2	35.9	4.8	46.3	79.8	126.1
160	25.8	17.1	49.4	19.7	36.9	5.3	53.7	79.3	133.0
CD (P=0.5)	0.7	0.4	2.1	0.6	1.4	0.1	1.8	3.7	3.6
1997-98									
Cropping Sequences									
Maize-Mustard	14.6	10.8	39.2	15.3	31.1	4.4	37.7	70.2	108.2
Soybean-Mustard	12.3	9.3	35.3	13.1	32.0	4.2	35.3	67.7	103.0
Moong-Mustard	15.9	12.6	41.8	16.7	34.2	4.6	37.9	72.5	110.4
Cowpea-Mustard	20.7	16.3	49.4	20.3	41.0	7.1	53.0	78.3	131.3
Fallow-Mustard	17.4	13.7	44.1	17.9	36.7	5.2	47.9	75.8	123.7
Dhaincha-Mustard	18.8	15.1	46.3	19.1	34.9	6.2	48.8	76.5	125.4
CD (P=0.5)	0.9	1.4	0.6	0.4	2.4	0.5	0.5	0.4	5.0
Nitrogen rates (kg N/ha)									
0	9.4	9.2	27.3	10.6	25.5	3.1	24.5	48.4	72.9
40	13.1	10.4	34.7	13.1	30.1	4.1	32.7	56.0	88.7
80	15.9	12.4	42.6	16.3	35.5	5.7	42.1	72.7	114.9
120	21.6	15.3	51.6	21.5	40.7	6.6	53.6	91.8	145.1
160	23.2	17.6	57.3	23.9	44.3	7.0	64.6	98.6	163.3
CD (P=0.5)	0.6	1.4	0.6	0.5	0.2	0.4	2.2	1.1	2.6

RESULT AND DISCUSSION

Cropping sequences

The Cowpea-Mustard sequence recorded highest nitrogen uptake in stem at different stages during both the years but was at par with Dhaincha-Mustard sequence at 30 DAS and maturity during 1996-97 and at 60 days stages during 1997-98. Nitrogen uptake in leaves increased between 30 and 60 days stage but thereafter decreased at 90 days after sowing during both the years (Table-2). In stem, the nitrogen uptake

Table 3. Dry Matter production (g/plant) in stem, leaves and siliquae at different stages and maturity as influenced by cropping sequences and nitrogen rates during 1996-97 and 1997-98.

Treatments	30 DAS		60 DAS		90 DAS		Maturity		
	Stem	Leaves	Stem	Leaves	Stem	Leaves	Stem	Siliquae	Total
1996-97									
Cropping Sequences									
Maize-Mustard	2.31	1.52	16.34	5.72	22.92	2.69	39.10	10.19	49.29
Soybean-Mustard	2.05	1.38	15.97	5.38	22.47	2.48	40.74	9.96	50.70
Moong-Mustard	2.44	1.72	16.69	5.92	23.12	2.73	41.34	10.36	51.70
Cowpea-Mustard	3.42	2.17	17.59	6.68	24.22	3.58	42.20	11.01	53.21
Fallow-Mustard	2.73	1.86	17.02	6.14	23.34	2.93	41.60	10.80	52.38
Dhaincha-Mustard	3.10	2.02	17.28	6.42	23.85	3.25	41.90	10.78	52.68
CD (P=0.5)	0.13	0.05	0.24	0.08	0.24	0.33	2.57	0.05	2.40
Nitrogen rates (kg N/ha)									
0	1.56	1.35	12.77	4.10	18.37	1.88	30.18	7.07	37.26
40	2.20	1.45	14.67	4.93	21.16	2.41	36.25	8.13	44.38
80	2.63	1.71	16.61	5.86	24.18	3.20	41.46	10.45	51.90
120	3.05	2.07	19.08	7.33	25.98	3.56	47.86	13.07	60.93
160	3.95	2.32	20.85	7.93	26.91	3.67	49.96	13.86	62.33
CD (P=0.5)	0.12	0.06	0.15	0.08	0.39	0.20	2.11	0.17	3.03
1997-98									
Cropping Sequences									
Maize-Mustard	2.14	1.50	15.17	4.48	19.84	2.23	37.78	7.96	45.74
Soybean-Mustard	1.86	1.34	14.86	4.64	20.50	2.06	37.45	7.76	45.20
Moong-Mustard	2.30	1.66	15.55	5.10	20.93	2.40	38.08	8.16	46.24
Cowpea-Mustard	2.88	2.10	16.86	5.70	22.06	3.02	39.16	8.88	48.04
Fallow-Mustard	2.49	1.82	15.99	5.27	21.49	2.62	38.43	8.44	46.87
Dhaincha-Mustard	2.68	1.98	16.60	5.47	21.22	2.83	38.79	8.70	47.49
CD (P=0.5)	0.10	0.05	0.53	0.12	0.67	0.27	0.30	0.01	0.30
Nitrogen rates (kg N/ha)									
0	1.47	1.33	11.71	3.36	16.68	1.37	28.53	4.40	32.92
40	1.96	1.43	13.11	4.10	18.80	1.90	32.25	6.18	38.43
80	2.28	1.70	15.21	5.11	22.18	2.70	38.61	8.18	46.80
120	3.02	2.00	18.21	6.25	24.15	3.26	44.91	11.52	56.43
160	3.21	2.18	20.95	7.02	23.73	3.41	47.10	11.39	58.40
CD (P=0.5)	0.69	0.04	0.58	0.17	0.52	0.06	0.30	0.07	0.29

at 60 and 90 DAS did not vary much but nitrogen content in leaves declined sharply at 90 DAS, was also highest in Cowpea-Mustard followed by Dhaincha-Mustard. The total nitrogen uptake and nitrogen uptake in stem and siliquae was significantly higher in Cowpea-Mustard sequence followed by Dhaincha-Mustard indicating the greater availability of nitrogen in soil preceding mustard.

The seed yield of mustard was higher in Cowpea-Mustard sequence and Dhaincha-Mustard sequences and both were at par (Table-4). Soybean-Mustard sequence recorded lowest seed yield. The oil content in seeds did not differ significantly due to cropping sequence but in treatment where legumes preceded mustard, it recorded higher value. Dhaincha-Mustard sequence recorded higher oil yield but was at par with Cowpea –Mustard sequence. All the cropping sequences had significantly higher oil yield over Soybean-Mustard sequence during both the years. This may be due to growing of legume crops increased the nitrogen availability to the succeeding mustard crop which resulted in vigorous plant growth and thereby increased seed yield. Similar results were also reported by Hegde (1994) indicated that legumes as preceding crops, inter crop or green manuring crop have helped in increasing the productivity and economizing fertilizer N needs of coarse cereal based cropping systems in western and southern regions of the country.

Nitrogen fertilization

The nitrogen uptake in stem, leaves and siliquae (Table-2) increased with the increase in nitrogen rates at different stages during both the years. However, 120 and 160 kg N/ha rates were at par at 90 days stages during 1997-98 for

Table 4. Seed yield (kg/ha), oil content (%) in seeds and oil yield (kg/ha) in mustard as influenced by different cropping sequences and nitrogen rates during 1996-97 and 1997-98.

Treatments	Seed yield (kg/ha)			Oil content (%)			Oil yield (kg/ha)		
	1996-97	1997-98	Pooled data	1996-97	1997-98	Pooled data	1996-97	1997-98	Pooled data
Cropping Sequences									
Maize-Mustard	16.5	15.9	16.2	39.8	39.6	39.7	658.3	639.3	648.8
Soybean-Mustard	12.6	12.2	12.4	39.0	38.0	38.5	495.9	477.5	486.7
Moong-Mustard	16.9	16.5	16.7	39.5	39.5	39.5	672.0	654.7	663.3
Cowpea-Mustard	18.4	17.7	18.0	40.5	40.1	40.3	733.8	712.7	723.2
Fallow-Mustard	17.5	16.8	17.1	40.8	40.5	40.6	771.2	693.9	732.5
Dhaincha-Mustard	18.2	17.8	18.0	40.7	40.8	40.7	744.8	730.9	737.5
CD at 5%	1.7	1.8		NS	NS		46.8	42.7	
Nitrogen rates (kg N/ha)									
0	13.0	12.6	12.8	40.2	39.6	39.9	524.9	562.7	562.7
40	15.3	14.9	15.1	40.5	40.1	40.3	624.9	603.3	603.3
80	16.6	15.9	16.2	40.1	40.1	40.1	670.5	655.2	655.2
120	18.9	18.4	187.6	40.0	39.9	39.9	734.7	737.1	737.1
160	19.6	19.0	19.3	39.6	39.7	39.6	771.6	758.7	758.7
CD at 5%	1.2	1.1		0.1	NS		5.1	8.7	

nitrogen uptake in stem. The application of nitrogen not only increased the nitrogen content (Table-1) in the plant at various growth stages and in different plant parts but also increased the root cation exchange capacity which enhanced the nitrogen absorption in plants (Kachroo, 1995; Sharma, 1986).

The highest-rates of dry matter accumulation (Table-3) was recorded with the application of 160 kg N/ha during both the years. However, at harvest stage, during 1996-97 and at 90 DAS during 1997-98, 120 and 160 kg N/ha rates were remained at par. The dry matter increased with the increase in nitrogen rates. Higher levels of nitrogen application increased the dry matter in stem and leaves during the initial stage of crop growth in both the years which not only resulted in higher production of dry matter due to more accumulation of photosynthates but also contributed towards the stronger reproductive phase, thereby resulting in higher seed yield at higher nitrogen rates.

Application of 120 kg N/ha recorded significantly higher seed and oil yield over all the lower nitrogen rates but was at par with 160 kg N/ha. The higher rates of nitrogen fertilization decreased the oil content significantly above 40 kg N/ha but increased the oil yield per ha. This may be due to the fact that more availability of nitrogen increased the proportion of proteinous substances in seeds. It is thus, conclusive that instead of keeping the land fallow mustard crop be preceded with Cowpea and application of 120 Kg N/ha be made for sustaining the production of Mustard.

Therefore, it is suggested that Cowpea-Mustard sequence along with 120 kg N/ha could be follow for higher yield of mustard. For sustained production, growing of Dhaincha before mustard is also desirable and nitrogen application could be reduced to 80 kg N/ha.

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EFFECT OF ROW RATIO AND PHOSPHORUS LEVEL ON YIELD AND QUALITY TRAITS OF LENTIL (*LENS CULINARIS*) + INDIAN MUSTARD (*BRASSICA JUNCEA*) INTERCROPPING

Uttam Kumar, I.P.S. Ahlawat*, VIPIN Kumar** and Vivek**

National Dairy Research Institute, Karnal, Haryana,
**Division of Agronomy, IARI, New Delhi -110012*
***SVBP Uni. of Agril. &Tech, Meerut, 250110 (UP)*

Abstract

A field experiment was conducted during two consecutive years viz., Rabi 2001 – 02 and 2002-03 at Agricultural Research Farm of J.V. College, Baraut (Baghpat), to find out the effect of row ratios (4:1 and 6:1) and phosphorus levels (40 and 60 kg P_2O_5/ha) on yield and quality of Lentil (*Lens culinaris*) + Indian mustard [(*Brassica juncea* L.) Czernj & Cosson] intercropping systems under North West Plain Zone of U.P. The highest land equivalent ratio (LER), were obtained at 4: 1 row ratio of Lentil + Indian mustard. Among the phosphorus levels tried, 60 kg P_2O_5/ha was found most economic.

Key Words: Intercropping, lentil, Indian mustard, Phosphorus level, Row ratio

Cultivation of lentil (*Lens cultivaris*) and Indian mustard (*Brassica juncea* L.) is common in India under rainfed conditions. Scientific approach of intercropping of these two crops increases the productivity per unit area per unit time (Ali, 1988) under a situation where two crops are grown in intercropping at a certain row proportion. Intercropping increases the cropping intensity, productivity and profitability, under optimum utilization of soil, water, nutrients and sunlight in time and space.

Phosphorus fertilization is important for grain legumes, having very specific key role in atmospheric nitrogen fixation. It improves root development, nodulation and seed quality. Although information is available on the phosphorus level in lentil and Indian mustard gown as sole crops, its effect on their intercropping system has not been thoroughly investigated. Hence the present study was undertaken to study the effect from ratio and phosphorus olevel on yield and quality of lentil + Indian mustard intercropping systems.

Material and Methods

The experiment was conducted during the winter seasons (Rabi) 2001-02 and 2002-03 at Agricultural Research Farm of J.V. College, Baraut (Baghpat) Uttar Pradesh, India. The soil of the experimental field was sandy loam, having pH 7.65, electrical conductivity (EC) 0.35 DS / meter, organic carbon 0.47 % and the available N, P_2O_5 and K_2O were 154.0, 9.05 and 201.0 kg/ ha., respectively. The treatments consisted of two row ratios of Lentil + Mustard (4:1 and 6:1) and sole crops of lentil and mustard to compare the differnt intercropping systems along with two levels of phosphorus (40 and 60 kg P_2O_5 /ha) through SSP. The experiment was conducted in split plot design with three replications. PL-639 of Lentil and Pusa bold cultivars of Indian mustard were used in the experiment at 30 cm row spacing. Crop were sown on 28 and 25 October, and harvested on 28 and 26

March during 2001-02 and 2002-03, respectively. Fertilizers were applied according to the treatment in soil in the form of urea and single super phosphate as basal at the time of sowing. Protein content of Lentil was calculated by multiplying the nitrogen content of seed by factor stander 6.25 (Jackson, 1967) and the oil content in the seed of Indian mustard was estimated by Pulse Nuclear Magnetic Resonance (NMR) Technique (Tiwari and Burk, 1980)

RESULTS AND DISCUSSION

Lentil

Effect of Row Ratio on yield

Results of the present investigation depicted in the table 1 that the grain yields of lentil were significantly low (6.33 and 6.87 in both the years) in 4:1 row ratio than 6:1 row ratio (7.25 and 7.58) and sole crop (9.29 and 10.41) . The highest yield attributes and the grain and straw yields were obtained with sole crop of lentil, which was statistically at par with that at 4:1 and 6:1 row ratio. Mishra *et al.* (2001) also obtained similar results. The reduction in yield attributes and yield of lentil was due to the shading effect of Indian mustard and lentil. Lentil in intercropping recorded 67.00 % (4:1) and 75.27 % (6:1) yield of the sole crop. Intercropping under different planting patterns adversely affected the seed and straw yields of lentil. The highest seed and straw yield of lentil 10.41 and 17.11 q/ha was obtained in sole crop of lentil while 6.22 q/ha and 11.19 q/ha of seed yield was minimum in 4:1 row ratio in both the years. Poor growth and developments of yields attributes are reduced plant density in different

Table 1. Effect of row ratios and P levels on yield and quality parameters of lentil in lentil and Indian nustard intercropping (pooled data of two seasons)

Treatment	Seed yield (q/ha)		Harvest index		Protein content (%)		Protein yield (kg/ha)	
	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03
Cropping pattern								
Sole mustard	-	-	-	-	-	-	-	-
Sole lentil	9.29	10.41	36.09	37.83	19.81	20.00	184.06	208.20
Lentil + Mustard (4:1)	6.33	6.87	36.13	37.66	20.00	20.06	126.60	137.83
Lentil + Mustard (6:1)	7.25	5.78	36.29	35.87	19.75	20.06	143.19	152.07
SEm±	0.13	0.12	0.37	0.39	0.12	0.13	1.51	1.60
CD at 5%	0.38	0.37	NS	NS	NS	NS	4.54	4.81
Fertilizers								
No fertilizer	6.53	7.02	37.19	37.63	19.69	19.75	128.56	138.65
30 kg N + 40 kg P_2O_5/ha	7.94	8.7	36.11	37.13	19.94	20.06	158.30	174.54
60 kg N + 60 kg P_2O_5/ha	8.4	9.13	35.49	36.81	20.19	20.25	169.58	184.88
SEm±	0.12	0.11	0.30	0.32	0.09	0.11	1.42	1.53
CD at 5%	0.34	0.32	NS	NS	0.29	0.31	4.30	4.54

planting patterns of intercropping finally resulted in poor seed and straw yield. Similar findings were obtained by Mandal (1997) and Prasad (2002).

Effect of Row Ratio on protein

Protein content in the seed of lentil was not influenced very much by different cropping systems. Highest protein content (20.06 %) was observed in 4:1 row ratio, while the lowest was 19.75 % in 6:1 row ratio, whereas total protein yield was declined in intercropping in different row ratios as compared with sole crop of lentil. The highest protein yield (208.20 kg/ha) was observed in sole lentil while it was lowest in 126.60 in 4:1 row ratio. The decrease protein yield under different planting patterns could be described to reduced seed yield of lentil in planting patterns, as compared with its sole stand. These results are in close conformity with findings of Mandal *et al.* 1997 and Kwatra and Mishra, 1999.

Effect of Phosphorus levels on yield

Phosphorus application exerted significant effected on seed yield with increasing dose of fertilizers. There was significant increase of 40 and 60 kg P_2O_5 /ha in seed yield over control, which gave a difference of 1.41 to 1.87 q/ha and 1.68 to 2.11 q/ha during 2001-02 and 2002-03, respectively. Application of 40 and 60 kg P_2O_5/ha improve the seed yield by 12.15 %, 12.86 % and 12.39, 13.00 % respectively in the year 2001-02 and 2002-03 as compared without phosphorus (Table 1). The doses of phosphorus were favorably effected the yield attributes and similar were the response in seed yield of lentil. These findings are in close conformity with those of Patel *et al* (2002).

Effect of Phosphorus levels on protein

Data presented in Table 1 shows that application of 60 kg P_2O_5 gave highest protein yield 169.58 and 184.88 kg/ha during 2001-01 and 2002-03 respectively, whereas it was minimum 128.56 and 138.65 kg/ha with out phosphorus. There is clear indication that protein yield may be increased up to 33.34 % with the increased dose of P_2O_5. As far as protein content is concern the highest (20.19 and 20.25 %) was found in 2001-02 and 2002-03, respectively, whereas, it was minimum (19.69 and 19.75 % in both the years, respectively) without phosphorus application. The protein content and yield was significantly increased due to the promote of plant nutrients, which are building blocks of proteins led to higher protein concentration, as also reported by Malik *et al.* (1991) and Das and Pramanick (1997).

Indian mustard

Effect of Row Ratio on seed yield

Sole crop of Indian mustard recorded significantly higher seed yield than intercropping. Highest seed yield (13.4 and 13.98 q/ha in the year 2001-02 and 2002-03, respectively) was obtained in sole crops of mustard, while it was lowest (7.03 and 7.50 q/ha in the year 2001-02 and 2002-03, respectively). It decreased due to less plant population per unit area with different row ratios of lentil + Indian mustard intercropping. Mishra *et al.* (2001) also reported similar results.

Effect of Row Ratio on oil

The oil content in seed of mustard was not influenced by various planting patterns in Inter cropping system. The highest oil content (39.53%) i.e. mustard was recorded in 4:1 row ratio whereas, it was minimum is 39.01% in sole mustard. The higher oil yield was (525.04 kg/ha) recorded in sold mustard whereas it was minimum (277.74 kg/ha) in 6:1 row ratio. The higher seed yield in sole crop resulted in maximum oil yield in sole crop than 4:1 and 6:1 plating patterns, which recorded lower yields (Mandal, 1997, Kwatra, 1999).

Effect of Phosphorus levels on yield

Phosphorus application up to 60 kg P_2O_5/ha significantly increased the plant height and yield contributing characters as compared with the low dose of phosphorus (40 kg P_2O_5) and without phosphorus. These doses improved the seed yield by 26.98 and 17.32%, respectively as compared to without fertilizer (Table 2). The increased P uptake could be attributed to higher seed yield. Bohra and Srivastava (2002), reported the similar findings.

Effect of Phosphorus levels on oil content

Fertilizer application had significantly reduced the oil content in both the years. But the total oil yield was increased with the increasing dose of phosphorus. Highest oil content was found 39.80 and 40.02 % with out phosphorus in the year of 2001-02 and 2002-03, respectively, similar results have also been reported by Sharma *et al.* (1999) and Sharma (1991). The total grain yield was found maximum (433.21 and 459.84 kg/ha) with the application of 60 kg P_2O_5/ha. It resulted 28.92% increase in oil yield may at higher dose of phosphorus. The decrease in oil content with an increase in fertilizer level might be due to

Table 2. Effect of row ratios and P levels on yield and quality parameters of mustard in lentil and Indian nustard intercropping (pooled data of two seasons)

Treatment	Seed yield (q/ha)		Harvest index		Protein content (%)		Protein yield (kg/ha)	
	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03
Cropping pattern								
Sole lentil	-	-	-	-	-	-	-	-
Sole mustard	13.40	13.98	24.18	24.46	39.04	39.53	525.04	336.02
Lentil + Mustard (4:1)	9.49	10.03	23.94	24.45	39.40	39.53	374.58	408.13
Lentil + Mustard (6:1)	7.03	7.50	25.17	25.52	39.40	39.38	277.74	433.21
SEm±	0.12	0.14	0.35	0.37	0.28	0.27	2.70	2.69
CD at 5%	0.35	0.43	1.05	1.12	0.85	0.83	8.14	7.73
Fertilizers								
No fertilizer	8.742	8.91	23.18	23.24	39.80	40.02	336.02	357.40
30 kg N + 40 kg P_2O_5/ha	10.38	10.88	24.69	25.17	39.18	39.40	408.13	430.63
60 kg N + 60 kg P_2O_5/ha	11.11	11.73	25.42	26.04	38.87	39.02	433.21	459.84
SEm±	0.12	0.14	0.32	0.34	0.25	0.25	2.69	3.33
CD at 5%	0.34	0.40	0.91	0.98	0.72	0.71	7.73	9.58

utilization of carbohydrate in protein formation. These results are in consistent with the results of Charian (2000).

The planting pattern had significant improvement in land equivalent ratio (LER). Lentil planted 4:1 ratio (Lentil + mustard) recorded maximum LER (1.39 and 1.38) during 2001-02 and 2002-03, respectively. However, planting pattern with 6:1 also recorded higher LER (1.31 and 1.26) than sole cropping pattern in both the years. Mishra *et al* (2001) also reported similar findings. This row ratio also gave the highest net returns and benefit: cost ratio, conforming the results of Singh *et al* (2000).

Table 3. Land equivalent ration (LER) lentil + mustard intercropping system

Treatment	Land equivalent ratio (LER)	
	2001-02	2002-03
Sole crop	-	-
Lentil + Mustard (4:1)	1.39	1.38
Lentil + Mustard (6:1)	1.31	1.26

Intercropping of lentil and Indian mustard significantly, increased the total productivity as compared with their sole crop. This was due to the increase in yield of component crop in the intercropping system and beneficial effect of widening of row ratio.

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EFFECT OF AZOTOBACTER AND NITROGEN ON YIELD AND NUTRIENT UPTAKE BY WHEAT

JAGPAL SINGH, SHISHU PAL SINGH[1] AND HARVENDRA SINGH

Department of Agricultural Chemistry and Soil Science, Raja Balwant Singh College Bichpuri, Agra (U.P.) 283 105

An integrated approach for use of biofertilizers with chemical fertilizers is considered as the need of hour, as biofertilizers are not replacement of fertilizers but can supplement their requirement. Therefore, its use in wheat, which is heavy feeder of nitrogen, is much more relevant. The increase in eco – friendly production of wheat can be made possible by nitrogen management through biofertilizers. Hence, present investigation was carried out to study the effect of use of biofertilizer and inorganic nitrogen on wheat production.

The experiment was carried out at research farm R.B.S. College Bichpuri, Agra during the winter season 2004 – 05 and 2005 – 06 in sandy loam soil. The available N, P and K contents in soil were 180, 9.2, 100 kg ha^{-1}, respectively with pH 8.2. The experiment was laid out in randomized block design with three replications comprising three nitrogen (60, 80 and 120 kg ha^{-1}) levels and two levels of Azotobacter (uninoculated and inoculated). The wheat grains were inoculated with the culture solution then dried under shade before sowing. Wheat UP – 2338 was sown on 22 and 24 November of 2004 – 05 and 2005 – 06, respectively, @ 100 kg ha^{-1} between 20 cm apart rows at a depth of 3 cm from the top of the soil in lines. The full dose of recommended phosphorus (60 kg P_2O_5 ha^{-1}), potassium (40 kg K_2O ha^{-1}) and half of nitrogen was applied as per treatments at the time of sowing as basal dose and rest of N at two equal splits, at crown root initiation and ear initiation stage. Adopting standard agronomic practices raised the crop. The crop was harvested at maturity and grain and straw yields were recorded. The grain and straw were analysed for their N and P content by adopting standard procedures. Soil samples collected after harvest were analysed for available N and P content (Jackson 1973).

The grain and straw yield of wheat increased significantly with inoculation of Azotobacter over no inoculation. The increase in grain and straw yield was 14.3 and 14.2 percent over uninoculated one, respectively. The increase in yield might have resulted from the growth regulating substances produced by application of Azotobacter besides fixation of additional nitrogen from atmosphere, thereby, increasing the nitrogen availability in the soil through out the crop growth. Kachroo and Razdan (2006) also reported similar findings. Increasing levels of N applied in wheat increased grain and straw yield significantly over 60 kg N ha^{-1}. Application of 180 kg N ha^{-1} significantly increased the grain and straw yields by 32.5 and 33.2 % compared with the 60 kg N ha^{-1}. Such spectacular responses to N application are obviously attributable to low available N status of the soil and relatively high N requirement of the crop. Similar results were obtained by Kachroo and Razdan (2006). Inoculation of Azotobacter increased the N uptake by

[1]Sardar Vallabhbhai Patel University of Agricultural and Technology, Meerut

Table 1. Effect of Azotobacter and nitrogen on yield, uptake of N and P in wheat and status in soil

Treatments	Yield (t ha^{-1})		Nitrogen (kg ha^{-1})		Phosphorus (kg ha^{-1})		Avail. N (kg ha^{-1})	Avail P (kg ha^{-1})
	Grain	Straw	Grain	Straw	Grain	Straw		
Azotobacter								
Uninoculated	4.46	12.55	101.6	70.5	9.5	12.9	176.1	8.8
Inoculated	5.10	14.34	118.5	86.3	11.6	16.0	184.0	8.9
SEm±	0.05	0.11	1.19	0.89	0.29	0.62	1.41	0.04
CD at 5%	0.15	0.34	3.60	2.70	0.89	1.86	4.25	NS
Nitrogen (kg ha^{-1})								
60	4.00	11.20	88.0	58.2	8.0	10.0	173.0	8.7
120	5.05	14.24	116.1	82.0	11.1	15.6	178.0	8.8
180	5.31	14.92	126.3	95.0	12.7	18.0	189.1	9.1
SEm±	0.06	0.14	1.46	1.09	0.36	0.76	1.73	0.05
CD at 5%	0.19	0.42	4.42	3.31	1.09	2.28	5.99	NS

grain and straw significantly over no uninoculation. The increase was owing to enhanced N content in the soil due to inoculation of Azotobacter. Maximum N uptake was associated with the highest (180 kg ha^{-1}) dose of nitrogen applied to wheat. The N uptake by wheat noted at 180 kg N ha^{-1} was significantly superior to reduced levels of N. This was mainly due to the fact that better N utilization by more healthy and vigorous plants under 180 kg N ha^{-1} level and resulting in more dry matter accumulation, which ultimately increased the uptake of nitrogen. Cumulative effect of increase in P content and grain and straw yield might have resulted in increase in P uptake with increasing N level up to 180 kg N ha^{-1}.

Available N content in soil increased significantly with Azotobacter inoculation as compared to uninoculation. The increase was owing to enhanced nitrogen content in the soil due to inoculation of Azotobacter. Available N status was higher at higher dose of N than lower doses of N and no nitrogen (control), which may be due to considerable gain of N content in the soil than control plots. The available P content in soil did not show any significant variation due to Azotobacter inoculation. Application of N did not affect the status of available P in soil after crop harvest significantly. However, a slight increase in available P status was noted with 180 kg N ha^{-1}.

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ECONOMIC EVALUATION OF *HELICOVERPA ARMIGERA* (HUBNER) ON TOMATO CROP IN MEERUT DISTRICT

S.P. Kurl and Anil Kumar

Department of Zoology, M. M. (P.G.) College, Modinagar- 201204, India

Tomato (*Lycopersicon esculentum* L.) is one of the most important vegetable crops cultivated for its fleshy fruits, and considered as commercial and diety vegetable crop. It ranks second to potato in importance but is first in the list of canned vegetables in entire world (Singh, 2005). While, Gajanana *et al*. (2006) reported tomato rank third next only to potato and brinjal in the production of vegetable in the country.

Tomato crop is attacked by several insect pests. They are serious ones and are responsible for great economic losses directly by feeding on leaves, stems and fruits and also indirectly by transmitting the virus diseases (Jandial and Kumar 2007). Among lepidopterous pests, the fruit borer *Helicoverpa (Heliothis) armigera* (Hubner) is most important pest (Kumar and Ramkishore 2005). Inspite of all possible agronomical practices and use of high yielding varieties, tomato yield is reduced by the fruit borer, *Helicoverpa armigera* and caused 14 to 45 percent loss to the fruit yield of tomato in different states of the country (Parihar and Singh 1985; Panday *et al*. 2006).

The strategy for the control of this pest on tomato crops is different from other crops because of the nature of utilization of tomatoes. Insecticides are the principal tool for pest control which however, produce resistant strains of the pests. Higher rates of pest mortality could not be achieved due to pesticides because *Helicoverpa armigera* larvae have developed resistance to the common pesticides used in India (Armes *et al.*, 1993). In Meerut area the problem of fruit borer of tomato can be more serious because of the favourable conditions for its multiplication by the present method of cultivation. Keeping this in view the present study is carried out to evaluate the economic losses by the pest and cost benefit rations by the chemical control measures.

To assess the field losses due to *Helicoverpa armigera* field experiments were laid out in a randomized block design with three replications at Modipuram, (Meerut) during 2004-06 in a plot size of 5.4m x 3.0m. In all experiments tomato varieties/ hybrids *viz.* Dev and Pusa Ruby were planted. The crops were raised under normal agronomical practices recommended for the region. In control plots, single spray with endosulfan 35 EC @ 0.05% started from flowering stage. For recording the damage by *Helicoverpa armigera*, 25 plants from central row of each replication were observed in all varieties at 55 days of transplanting. At picking, two lots of fruit each from replication were observed from spray and unsprayed plots accommodated with different varieties. The healthy and damage plants were counted and weighted separately. The percent fruit damaged both number and weight were calculated.

The economic of the control measures calculated were based on plant protection cost Rs. 2190, Rs. 2580 and Rs. 3000 during 2004, 2005 and 2006, respectively and tomato price was Rs. 550, Rs. 515 and Rs. 680 per quintal during 2004, 2005 and 2006, respectively at Meerut mandi, achieved from unsprayed crop by applying the formula:

Yield loss = yield in protected plot – yield in unprotected plot

Profit = Price of Tomato fruits of protected plot – Price of tomato fruit in unprotected plot

$$\text{In secticidal} = \frac{\text{Cost of Pest Control (Rs./ha)}}{\text{Price of the Produce (Rs./ha)}}$$

The results on the percent fruit damage presented in Table 1, showed that entensity of percent fruit damage was significantly high during 2005 in both the varieties than that of during 2004 and 2006. The findings of three years also revealed that the fruits of variety Dev were heavily damaged by fruit borer, ranging from 20.1% to 30.6% by number and from 34.3% to 35.9% by weight as compared to variety Pusa Ruby in which the fruit damage was ranged from 8.9% to 14.2% by number and from 14.8% to 17.3% by weight.

The highest fruit damage was observed in Dev, it was recorded as 20.1, 30.6 and 21.8% by number, 34.3%, 35.9% and 34.4% by weight during 2004, 2005 and 2006, respectively. Whereas, the lowest fruit damage was recorded in Pusa Ruby, which was recorded as 8.9%, 14.2% and 9.9% by number and 14.8%, 17.3% and 15.6% by weight during 2004, 2005 and 2006, respectively (Table 1).

Three sprays of Endosulfan-35EC (0.05%) gave an additional profit of Rs. 56722.50 and Rs. 20211.50 in 2004, Rs. 54919.75 and Rs. 21558.05 in 2005 and Rs. 70712.00 and Rs. 26430.40 in 2006 in Dev and Pusa Ruby, respectively (Table 2).

Pooled data of three years indicated that on an average the fruit damage 24.2% and 11.0% by number and 34.8% and 15.9% by weight was recorded in Dev and Pusa Ruby, respectively. Three sprays of Endosulfan-35EC (0.05%) resulted in an additional benefit of Rs. 60846.93 and Rs. 22782.45 in Dev and Pusa Ruby, respectively (Table 2). These findings are in conformity with the observations of Kumar *et al*. (1999) and Thakur and Singh (2000).

Table 1. Fruit damage caused by *H. armigera* (Hubner) on tomato crop during 2004–06.

Variety	Fruit Damage (%)							
	By number				By weight			
	2004	2005	2006	Average	2004	2005	2006	Average
Dev	20.1 (25.82)	30.6 (33.39)	21.8 (27.34)	24.2 (29.06)	34.3 (35.72)	35.9 (36.59)	34.4 (35.55)	34.8 (37.36)
Pusa Ruby	8.9 (16.58)	14.2 (21.73)	9.9 (17.91)	11.0 (18.11)	14.8 (22.00)	17.36 (24.09)	15.6 (22.47)	15.9 (22.66)
SEm(±)	(1.66)	(0.71)	(1.06)	(1.23)	(1.37)	(1.56)	(2.38)	(1.18)
CD at 0.05%	(5.12)**	(2.19)**	(3.27)**	(3.79)**	(4.22)**	(4.81)**	(7.33)**	(3.64)**

The figure parentheses are $\sqrt{x+1}$ value

** Significant at 1%

Table 2. Assessment of losses due to *H. armigera* in tomato crop during 2004-06.

Year	Variety	Yield (q/ha)		No. of	Cost of	Damage	Increase	Net
		Sprayed	Unsprayed	Spraying	Spraying (Rs/ha)	Fruit (q/ha)	Income (Rs/ha)	Profit (Rs/ha)
2004	Dev	312.33	205.20	3	2190	107.13	58921.50	56722.50
	Pusa Ruby	275.17	234.44	3	2190	40.73	22401.50	20211.50
2005	Dev	310.99	199.34	3	2580	111.65	57499.75	54919.75
	Pusa Ruby	270.93	224.06	3	2580	46.87	24138.05	21558.05
2006	Dev	315.11	206.71	3	3000	108.4	73712.00	70712.00
	Pusa Ruby	277.44	234.16	3	3000	43.28	29430.40	26430.40
2004-06	Dev	312.81	203.75	3	2590	109.06	63436.93	60846.93
	Pusa Ruby	274.51	230.89	3	2590	43.62	25372.45	22782.45

Price of tomato during 2004 –Rs. 550=/q
2005 –Rs. 515=/q
2006 –Rs. 680=/q

It may be concluded that assessment of crop losses due to *Helicoverpa armigera* (Hubner) in two varieties of tomato *viz,* dev and Pusa Ruby were undertaken to work out the economic losses. Pooled data of three years indicated that on an average the fruit damage was recorded 24.2% and 11.0% by number and 34.8% and 15.9% by weight was recorded in Dev and Pusa Ruby, respectively. Three sprays of Endosulfan- 35EC (0.05%) resulted in an additional benefit of Rs. 60846.93 and Rs. 22782.45 in Dev and Pusa Ruby, respectively.

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YIELD RESPONSE IN MAIZE (*ZEA MAYS* L.) BASED CROPPING SYSTEM THROUGH DRIP FERTIGATION

K. Ramah, P. Santhi and K. Ponnuswamy

Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore – 641 003

The annual food grain requirement of India works-out to be 450 million tonnes by the year 2050 and the per capita availability in terms of average utilizable water resources, which was 6008 m^3 in 1947 (presently 1250 m^3) is expected to dwindle down to 760 m^3 (Anon., 2006). Agriculture, a main stay in India, accounts for 25 per cent of the Nations Gross Domestic Product and agricultural sector is the largest consumer of water. The overall efficiency of the flood irrigation system range between 25 to 40 per cent. To meet the food security, income and nutritional needs of the projected population in 2020 the food production in India will have to be almost doubled. Adoption of micro irrigation, may help in saving significant quantity of water and increase the quality and quantity of produce. All these emphasize, the need for water conservation and improvement in water-use efficiency to achieve 'More Crop per Drop'.

The area under maize is expected to increase in future due to ever increasing demand of maize grains in poultry and animal feed industries. Micro irrigation related research in millets is very limited. Input information on optimal schedules for micro-irrigation and fertigation to various millets and planting geometry for micro-irrigation will have to be generated from the current levels thus enabling the option of micro-irrigation for the millet crops. Among different cropping systems tried in garden lands of western zone of Tamil Nadu, maize based cropping system recorded higher level of biosynthates (carbohydrate, protein and fat). While considering from the nutrient point of view, this system would be considered essential, though the vegetable - based system would be profitable (Ramesh, 2002). Considering all these factors, the present study was initiated to determine the effect of different fertilizer levels on growth of maize.

Field experiments were conducted at Agricultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore, from July 2006 to August 2007 to study the effect of varying irrigation regimes and fertilizer levels in maize based cropping system. The experimental soil was texturally classified as sandy clay loam and the available status of nitrogen in the soil was low, with medium phosphorus and high in potassium. The experiment was laid out in split plot design with three replications. The experiment consisted of 3 irrigation regimes in main plots *viz.*, I_1 - Drip irrigation at 75 % WRc (computed water requirement of crop), I_2 - Drip irrigation at 100 % WRc, I_3 - Drip irrigation at 125 % WRc and 4 fertilizer levels in sub plots *viz.*, F_1 - 75 % RDF, F_2 - 100 % RDF, F_3 - 125 % RDF and F_4 - Drip irrigation + 100 % RDF by soil application. One control treatment with conventional furrow irrigation and soil application of 100 per cent recommended dose of fertilizer was also included for comparison.

The drip irrigation and fertigation was scheduled once in three days as per the treatment schedule for each crop in the cropping system. The test crops chosen for the cropping system were "Maize (CoHM(5))", "Sunflower (Co4)" and "Beetroot (Ruby Queen)". During July to October 2006, hybrid maize was grown as test crop with a spacing of 75 / 45 x 20 cm in paired row technique. While during January to March 2007, the test crop was sunflower grown in the same field with a spacing of 75 / 45 x 30 cm followed by beetroot during June to August 2007 with a spacing of 20 x 15 cm (four rows), so as to maintain the recommended population. In the farmer's method (furrow irrigation), spacing of 60 x 20 cm, 60 x 30 cm and 30 x 10 cm were followed in ridges and furrow system for maize, sunflower and beetroot respectively. The fertilizer sources for supplying NPK through drip irrigation were urea, mono ammonium phosphate (12:61:0 NPK) and muriate of potash, respectively. Fertigation was done through ventury, once in three days starting from 12 DAS to 71 DAS for maize, 12 DAS to 62 DAS for sunflower and 12 DAS to 49 DAS for beetroot which was regulated by taps provided near the take points of the sub main.

Influence of drip irrigation and fertigation levels on yield parameters

The yield parameters and yield of maize, sunflower and beetroot are furnished in Tables 1, 2 & 3. All the yield parameters were significantly affected by both irrigation as well as fertilizer levels.

The yield attributing characters of maize (cob length, cob girth, cob weight, number of grain rows cob^{-1}, number of grains cob^{-1} and hundred grain weight), sunflower (head diameter, number of grains head^{-1}, number of filled grains head^{-1}, filling percentage and hundred grain weight) and beetroot (root girth, root volume and root fresh weight) were significantly influenced by drip irrigation regimes and fertigation levels. The yield attributing characters of all the three crops were higher under drip irrigation at 100 and 75 per cent WRc and with 125 and 100 per cent RDF through fertigation. Higher irrigation level (125 per cent WRc) resulted in lower yield attributing characters. Similarly fertigation at 75 per cent RDF and application of RDF on soil with drip irrigation (F_4) resulted in lower yield parameters in all the three crops. Higher fertigation dose of 125 per cent RDF resulted in higher yield parameters. Better crop growth at higher nutrient levels might have influenced the yield attributes favourably. This finding was in accordance with the findings of Ranjodh Singh (1983) and Narayanasamy *et al.* (1994). Prasad *et al.* (2001) observed that the filled grains head^{-1}, number of achenes head^{-1} and 1000 grain weight of sunflower was higher under high N rate (60 kg ha^{-1}). Similarly higher yield attributes were recorded under 125 per cent fertigation in sugarbeet (Rajasekaran, 2007).

Roots can easily translocate absorbed water from the soil where available soil moisture content was optimum at 100 per cent WRc. Required energy for water absorption was less under these treatments and ultimately led to easy energy translocation to the reproductive parts. Also the root growth under these treatments was high which contributed to higher moisture translocation from the soil to the plant parts. The nutrients were applied in adequate quantity and were in easily available form which created more conducive environment for the roots to

Table 1. Influence of drip fertigation on yield attributes and yield of maize

Treatments	Cob length (cm)	Cob girth (cm)	Cob weight (gm)	No. of grains rows cob^{-1}	No. of grains cob^{-1}	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})
I_1	18.4	15.0	209.7	15.0	444	6770	10009
I_2	19.1	15.7	215.0	15.4	462	7151	10730
I_3	17.2	14.1	203.9	14.6	424	6375	9344
CD (p=0.05)	0.98	1.01	5.60	0.41	24.9	406.7	825.3
F_1	17.8	14.5	197.4	14.4	420	6423	9604
F_2	18.6	15.1	217.2	15.4	463	7001	10323
F_3	19.3	15.8	234.1	16.1	491	7312	10727
F_4	17.2	14.3	189.4	14.2	400	6327	9457
CD (p=0.05)	0.70	0.65	18.64	0.76	38.4	315.6	680.2
I at F							
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS
F at I							
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS
Farmer's method	17.1	13.7	186.0	14.0	386	5992	9073
FM vs IF							
CD (p=0.05)	1.27	0.98	19.52	1.22	40.4	520.9	761.4

I_1 - 75 % WRc; I_2 - 100 % WRc; I_3 - 125 % WRc; FM - Farmer's method
F_1 – 75 % RDF through drip; F_2 – 100 % RDF through drip; F_3 – 125 % RDF through drip ;
F_4– Drip + 100% RDF soil applcation

absorb the nutrients more effectively and at higher rate when compared to other treatments. The growth parameters were also higher under these treatments which might have contributed to higher yield parameters. All these reasons coupled together and resulted in higher yield attributing characters in all the three crops.

In general, the yield parameters under higher irrigation regime (I_3) and under soil applied fertilizer treatment (F_4) were comparable with the surface irrigation method. The reason might be due to the lower availability of nutrients and higher loss of nutrients through leaching when applied through conventional method (soil applied) with high irrigation both under 125 per cent WRc and surface irrigation method. Miller *et al.* (1976) reported that in surface irrigation the plant nutrients leached beyond the root zone due to higher quantity of irrigation water. Excessive irrigation resulted in lower yields and yield quality (head weight and head length) in Romaine lettuce (*Lactuca sativa* L. cv. Parris Island Cos) (Thompson and Doerge, 1995b) and created conditions conducive to N losses.

Table 2. Influence of drip fertigation on yield attributes and yield of sunflower

Treatments	Head diameter (cm)	No. of seeds head^{-1}	No. of filled seeds head^{-1}	Seed filling %	Seed yield (kg ha^{-1})	Oil yield (kg ha^{-1})
I_1	20.1	1170	1058	90.3	1858	737
I_2	21.6	1231	1127	91.5	1951	775
I_3	18.1	1114	980	87.9	1737	689
CD (p=0.05)	2.14	77.7	80.2	1.11	138.6	55.0
F_1	18.6	1143	1018	89.0	1765	701
F_2	21.0	1192	1085	90.9	1953	776
F_3	21.6	1215	1114	91.7	2038	809
F_4	18.4	1137	1002	88.1	1637	650
CD (p=0.05)	1.23	35.1	32.3	0.89	133.4	52.9
I at F						
CD (p=0.05)	2.80	93.0	93.0	NS	NS	NS
F at I						
CD (p=0.05)	2.13	60.9	56.0	NS	NS	NS
Farmer's method	17.2	1024	891	87.0	1450	576
FM vs IF						
CD (p=0.05)	2.25	75.7	73.5	1.68	231.2	107.3

I_1 - 75 % WRc; I_2 - 100 % WRc; I_3 - 125 % WRc; FM - Farmer's method
F_1 – 75 % RDF through drip; F_2 – 100 % RDF through drip; F_3 – 125 % RDF through drip ;
F_4– Drip + 100% RDF soil applcation

Influence of drip irrigation and fertigation levels on yield of crops

Maize

The yield data showed the favourable effect of drip fertigation on the grain and stover yield of maize. Drip irrigation given based on 100 per cent WRc of the crop produced higher yield (7151 kg ha^{-1}) however it was comparable with drip irrigation at 75 per cent WRc. This result was in concordance with the findings of Suhas Bobade *et al.* (2002) in drip irrigated brinjal. Sorensen and Butts (2005) also reported that there was no yield reduction in corn or peanut when irrigated at 75 per cent of the estimated water use compared with the 100 per cent irrigation level.

Increasing the irrigation level to 125 per cent of WRc resulted in 12 and 15 per cent lower grain and stover yield of maize, respectively compared to 100 per cent WRc. Similar findings were observed by Darusman *et al.* (1997), where 13 per cent corn grain yield was reduced due to higher (125 per cent ET) irrigation when compared to 100 per cent ET. Excessive irrigation not only increases the non beneficial components of the water

Table 3. Influence of drip fertigation on yield attributes and yield of beetroot

Treatments	Root girth (cm)		Root weight (gm)		Root yield (kg ha^{-1})
	45 DAS	Harvest stage	45 DAS	Harvest stage	
I_1	10.87	29.71	38.2	472.9	18975
I_2	11.08	31.47	40.4	503.0	20147
I_3	9.53	27.00	34.6	416.9	17142
CD (p=0.05)	0.995	2.144	2.96	39.95	1281.7
F_1	9.64	28.40	34.8	440.6	17800
F_2	10.90	30.55	41.1	480.2	19511
F_3	12.21	31.20	43.1	502.7	20907
F_4	9.21	27.43	32.0	433.5	16800
CD (p=0.05)	0.804	1.217	3.11	30.69	1478.7
I at F					
CD (p=0.05)	NS	NS	5.48	60.41	NS
F at I					
CD (p=0.05)	NS	NS	5.38	53.16	NS
Farmer's method	7.84	23.46	29.3	397	14530
FM vs IF					
CD (p=0.05)	1.332	2.41	4.93	54.1	2331

I_1 - 75 % WRc; F_1 - 75 % RDF through drip
I_2 - 100 % WRc; F_2 - 100 % RDF through drip
I_3 - 125 % WRc; F_3 - 125 % RDF through drip
FM - Farmers method; F_4 - Drip irrigation + 100 % RDF by soil application

balance, but may actually decrease yields of drip-irrigated corn. Excessive irrigation has both economic costs, such as pumping costs, and social costs such as waste of the water resource and excessive drainage (Lamm *et al.*, 1995).

Regarding the fertilizer levels, applying 125 per cent RDF as fertigation produced the highest yield. Though 125 per cent RDF recorded the highest yield, it was statistically on par with the application of 100 per cent RDF as fertigation. Higher rates of nutrients resulted in better translocation of assimilates from source to sink. Soil application of RDF with drip irrigation recorded significantly lower grain and stover yield which was 16 and 13 per cent lower than 125 per cent RDF respectively, but was statistically similar to the application of 75 per cent RDF through drip.

Sunflower

Drip irrigation regimes and fertilizer levels significantly influenced the grain and oil yield of sunflower. Sunflower treated with 100 and 75 per cent WRc of irrigation recorded higher yield. Crops irrigated with increased level of irrigation at 125 per cent WRc resulted in the lowest yield, which was 12 per cent lower than 100 per cent WRc. Similar findings were observed by Thompson and Doerge (1995a), in mustard and spinach which revealed that excessive irrigation resulted in lower yield and N uptake than the optimum level of irrigation. Excess water applications have caused deficiencies in soil aeration, leaching of nutrients and subsequent yield reductions (Wacquant *et al.*, 1975 and Feddes *et al.*, 1978).

However, the yield was found to be increased while increasing the fertilizer dose upto 125 per cent RDF through drip. Applying fertilizer at the rate of 125 per cent RDF through drip irrigation resulted in higher yield, but was significantly on par with 100 per cent fertigation level. Drip irrigation with soil application of RDF produced lower yield of 25 per cent less than 125 per cent RDF, however it was significantly comparable with fertigation at 75 per cent RDF. The increase in yield under 125 and 100 per cent RDF might be due to the fact that fertigation at higher dose obviously resulted in higher availability of all the three (NPK) major nutrients in the soil solution which led to higher uptake and better translocation of assimilates from source to sink thus in turn increased the yield. The increase in yield under 100 per cent WRc and 125 per cent RDF was due to the performance of all crop growth and yield attributing characters due to better availability of soil moisture and nutrients throughout the crop growth period under drip fertigation system. This was in concordance with the findings of Gutal *et al.*, (1989).

Beetroot

Root characters are very important for root crops such as beetroot. The relationship with root girth, fresh root weight and root volume are directly proportional to beetroot yield. Drip irrigation at 100 and 75 per cent WRc and fertigation at 125 and 100 per cent RDF resulted in higher root yield (20147, 18975, 20907 and 19511 kg ha^{-1}, respectively) due to higher root characters. Since more availability of nutrients with adequate moisture might have enhanced the root proliferations resulting in enhanced root girth and fresh root weight which ultimately resulted in significant root yield. Growth of root in general is stimulated by phosphorus, hence higher application of P (160 kg ha^{-1}) for root crops such as beetroot would have encouraged early root growth and higher root biomass with greater P use efficiency and greater uptake of nutrients under drip fertigation with specialty fertilizer like mono ammonium phosphate. Similar results were reported by Pandey *et al.* (1996) in tomato and Thompson *et al.* (2003) in subsurface drip-irrigated broccoli. Similarly highest pod yield of bhendi was obtained with the crop irrigated through drip at 1.00 Epan and fertigated with 120 N kg ha^{-1} (higher dose) and was 54 and 57 per cent higher over furrow irrigated crop during 2003 and 2004, respectively (Bhanu Rekha *et al.*, 2006). Rajasekaran (2007) reported similar findings of higher yield of sugarbeet under 125 per cent drip fertigation.

The root yield was lower (17142, 17800 and 16800 kg ha^{-1}, respectively) in the excess irrigated plots (125 per cent WRc – I_3), lower fertigated plots (75 per cent RDF – F_1) and in soil applied plots

(F_4). The root yield under 125 per cent WRc was 18 per cent lower than 100 per cent WRc. Shrivastava *et al.* (1994) also observed that when drip irrigation was coupled with the increase in PE ratio, there was a decrease in the tomato yield. In general, greater amounts of N were needed for optimum yield as irrigation amount increased. Excessive irrigation generally lowered the marketable yields, head weight and head length in leaf lettuce (Thompson and Doerge, 1996a); yield in tomato (Locascio and Smajstria, 1996). Yield losses were more common due to excessive irrigation rather than deficient irrigation in cauliflower. Higher rate of N were needed to maximize yields when excessive amounts of irrigation water were applied (Thompson *et al.*, (2000).

The yield obtained in F_4 (drip + 100% RDF soil application) treatment was 24 per cent lower than 125 per cent RDF. It is self explanatory that over irrigation and lower fertilization had not increased the plant growth as well as root growth which might be the cause for lower yield. Under surface fertilized plots, the entire quantity of P (160 kg ha^{-1}) was applied as basal on the day of sowing, where the P gets fixed up in the soil profile and when the roots emerge and grows, it was able to utilize the available P alone which are very low due to fixation in the soil. Whereas under drip fertigation, the P nutrient in the form of mono ammonium phosphate which is easily soluble in water was fertigated from 12th day after sowing and fertigated once in three days up to 50 days. So the crop was able to absorb more P throughout the crop growth period with very minimum loss of nutrients. This might be the reason for higher root growth under drip fertigated treatments when compared to surface applied plots (F_4) and control plots (surface irrigation). The results obtained by Sundar Raman *et al.* (2000) indicates that fertigation with soluble fertilizers like urea, MAP and Multi-K can increase the yield and quality of gherkins and 25 per cent of the fertilizer can be saved without affecting the yield. Sivanappan (1975) reported 55.4, 40.2 and 13.5 per cent yield increase in beetroot, tomato and radish, respectively under drip irrigation when compared to furrow irrigation.

It was observed that the yield attributing characters and yield of all the three crops were higher under drip irrigation at 100 per cent WRc and with 125 per cent RDF through fertigation. Higher irrigation level (125 per cent WRc) resulted in lower yield attributing characters and yield. Similarly fertigation at 75 per cent RDF and application of RDF on soil with drip irrigation (F_4) resulted in lower yield parameters and yield in all the three crops.

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EFFECT OF VARITIES AND CROP GEOMETRIES ON THE GROWTH, YIELD, QUALITY AND ECONOMICS OF INDIAN MUSTARD (*BRASSICA JUNCEA*)

YOGESH KUMAR SINGH, RAM PRAKASH GOLA, AND JAGVIR SINGH*

Department of Agronomy, Chaudhary Charan Singh SDS, PG College, Iglas (Aligrarh) U.P.
**Division of Agronomy IARI, New Delhi – 12*

Indian mustard are the most popular edible oil crops of Indian. Adoption of improved varieties and suitable crop management practices are important factors for improving their productivity. Nearly 50-70% of improvement in the production of rapeseed and Indian mustard is due to adoption of improved technologies. Maintenance of optimum and uniform plant population is a prerequisite for obtaining high yields. The optimum plant population and crop geometry would, however very with the species/ variety soil type and soil fertility. Fertilizers and improved varieties are two most important agronomic factors which play pivotal role in achieving the potential yield of any crop. The response of different varieties in one environment or a single variety in different environment can be quite different with varying plant population. Information on plant characters of mustard varieties in relation to varying spacing for new emerging high yielding varieties is needed to identified for updating the knowledge and yield maximization. Keeping above in view an experiment was conducted to determine the effect of varieties and crop geometries on the yeild of mustard crop.

The investigation was carried out during the winter (rabi) season of 2004-2005 at Agronomy research form of CCS Shiv Dhan Singh PG College, Iglas (Aligarh), Uttar Pradesh. The soil of experimental field was sandy loam in texture having low in organic carbon and available potash and slightly alkaline in reaction with PH 7.4. The experiment was laid out in split-plot design with 4 replications. Main plots were treated with row spacing 30*15cm, 45*15cm, 20/40*15cm and 30/60*cm. Sub plot consisted of 3 varieties of mustard viz. Rh-30, Pusa Jai Kishan and Type-59.

Mustared crop (all the varieties) was sown on 7th November 2004 at seed rate of 5Kg/ ha. The entire dose of P_2O_5 (03 kg/ha), $ZnSO_4$ (25kg/ha) and half dose of N(40kg n/ha) was applied at the time of sowing and remaining half does of nitrogen was applied after first irrigation. The source of nitrogen and phosphorus were urea (45%N) and single super phosphate (16% P_2O_5 respectively).

Effect of Genotype

Genotypes differed significantly among themselves in respect of growth measured in terms and plant height and dry matter accumulation. Highest plant height and dry matter accumulation was observed in T-59 variety which was significantly higher than that of RH-30 and Pusa Jai Kisha. The difference in height and dry matter accumulation of various cultivars may be attributed to the variations in genetic constitutions they inherit. Among various varieties of mustard, Pusa Jai Kishan recorded the significantly shortest plant height and lowest dry matter. Mustard cultivar T-59 recorded significantly higher seed yield, oil content (40.7%) and oil yield (69.7kg/ ha) than RH-30 and Pusa Jai Kishan however variety RH-30 found remarkably superior over Pusa Jai Kishan in term of

Table 1. Effect of varieties and crop geometries on the height, seed yield, oil content, oil yield and economics

Treatments Spacing (CM)	Plant height at 120 DAS (cm)	Dry matter accumulation/ Plant at 60 DAS(g)	Seed yield (kg/ha)	Oil content (%)	Oil yield (kg/ha)	Net return/ ha (Rs)
30*15	182.0	6.6	1701	40.3	687	13875
45*15	177.6	8.3	1524	40.0	614	11484
20/40*15	182.0	7.4	1800	40.4	730	15262
30/60*15	181.0	8.0	1438	40.6	582	10194
SE m+	2.80	0.13	41	0.27	18	
CD at 5%	NS	0.44	131	NS	59	
Varieties	-	-	-	-	-	-
RH-30	180.0	7.6	1610	40.4	650	12936
Pusa Jai Kish	174.0	7.4	1531	40.1	613	11751
Type-59	187.0	7.8	1705	40.7	697	14361
SE m+	0.72	0.02	12	0.06	4.3	
CD at 5%	2.12	0.08	37	0.20	12.9	

seed production, oil content and oil yield respectively. Mustard variety T-59 gave extra profit of Rs. 1425 and Rs. 2610 over RH-30 and Pusa Jai Kishan. Whereas variety RH-30 gave more profit of Rs. 1185 over Pusa Jai Kishan. The results corroborates the findings of Bali et al (2000) and Singh et al (2003).

Effect of Crop Geometries

Crop geometries failedto shown any difference in plant height. Spacing 40*15cm and 30/60*15 cm being at par recorded significantly more dry matter accumulation per plant then 30*15 cm and 20/40*15 cm. Plant density of 30*15 cm and 20/40*15 cm produced significantly higher seed yield. This could mainly be attributed to more number of plants per units area under these spacing. All the treatments of spacing did not bring about any significantly difference in oil content. Oil yield was higher in 30*15 cm and 20/40*15 cm spacing. This could mainly be attributed to higher seed yield production under these spacing. Highest net profit was earned when plant spacing was 20/40*15 cm followed by 30*15 cm and lowest net return was obtained when the plant spacing was 30/60*15 cm in paired row system. Similar results had also been reported by Sharma et al (1997), Thakur (1999), Butter nad Aulakh (1999) and Singh et al (2003).

It was observed that cultiver type 50 recorded higher yield of oil and net return than cultivar RH-30 and pusa Jaikishan. Among the treatment of plant spacing 20/40 x 15 c, recorded highest yield of oil, and net return.

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EFFECT OF CADMIUM AND SULPHUR ON YIELD AND NUTRIENTS UPTAKE OF OAT

J.S. DESHWAL[1], SHISHU PAL SINGH[2], VINAY SINGH AND VIKAS BALITAN[3]

Department of Agricultural Chemistry and Soil Science, Raja Balwant Singh College Bichpuri, Agra (U.P.) 283 105

The present study was undertaken to evaluate the effect of Cd and S on yield and nutrients uptake by oat. A pot culture experiment was conducted on a sandy loam soil having pH 8.0, EC 0.19 dSm^{-1}, organic carbon 3.9 gkg^{-1}, available N 78 mg kg^{-1}, available $CaCl_2$ (0.15%) S 8.5 mg kg^{-1} and DTPA extractable Cd 0.06 mg kg^{-1}. Air dried about five kg of soil was filled in polyethylene lined earthen pots. The treatments consisting of four levels each of Cd (0, 12.5, 25.0 and 50.0 mg kg^{-1}) and S (0, 12.5, 25.0 and 50.0 mg kg^{-1}) as cadmium chloride and elemental S, respectively. Treatments were applied at sowing with three replication. A basal dose of N, P and K was applied @ 50, 30 and 20 mg kg^{-1}, respectively through reagent grade salts. Ten seeds of oat (variety Kent) were sown and irrigated with deionised water as and when required. After emergence and setting, five plants were kept for observation and crop was harvested at maturity. Grain and straw samples were washed and dried as per standard methods and then oven dried at 60^0 C. Grain and straw samples were ground and digested in diacid mixture (HNO_3 + $HClO_4$) and analyzed for Cd on atomic absorption spectrophotometer and P by ammonium molybdrate vanadate yellow colour method. Nitrogen in the samples was determined by Kjeldahl method.

The grain and straw yield of oat decreased significantly with increasing levels of Cd (Table 1). The decrease in grain yield was from 3.98 g /pot at control to 2.50 g/pot with 50 mg Cd kg^{-1}. This decrease in yield due to Cd could partly owing to be its toxic effect and partly due to ionic imbalance. These results corroborate the findings of Dahiya et al. (1987) in maize and Sarkunan et al. (1998) in rice. The grain and straw yield of oat increased significantly up to 25 mg S kg^{-1} level as reported by Sarkunan et al. (1998).

Protein content in oat improved with Cd and S addition. Since, S is a constituent of many amino acids viz. cystine, cysteine and methionine, applied S increased the amounts of these amino acids and protein content in grain. The data (Table 1) indicate that N uptake by oat crop decreased significantly by the addition of Cd. The percent decrease in N uptake by grain and straw over control due to 12.5, 25.0 and 50.0 mg Cd kg^{-1} was 10.4 and 3.2, 23.9 and 16.7 and 33.4 and 22.3 percent, respectively. This decrease might be due to decreased yield at higher level of Cd which resulted in less absorption of N. Application of S increased the uptake of N significantly from 55.7 mg N pot^{-1} at control to 76.7 mg N pot^{-1} at 50 mg S kg^{-1}. Application of Cd increased its uptake by oat grain and straw significantly. This increased Cd uptake with increased Cd levels is primarily due to increased Cd availability in soil. A decrease in Cd uptake at highest level of Cd was

[1]CSWCRTI Chhalesar, Agra, [2&3]S.V.B.P. Univ. of Ag. and Tech., Meerut

Table 1. Effect of Cd and S levels on yield (g /pot) and uptake of N, S (mg pot-1) and Cd (µg pot-1) by oat grain and straw

Treatments	Yield		Protein %		Nitrogen		Cadmium		Sulphur	
(mg kg-1)	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Cadmium										
0.0	3.98	5.99	12.87	3.92	81.9	37.6	10.5	34.6	11.4	11.1
12.5	3.50	5.51	13.11	4.13	73.4	36.4	12.6	59.4	9.1	8.8
25.0	2.87	4.56	13.57	4.29	62.3	31.3	16.9	66.2	7.1	6.7
50.0	2.50	4.07	13.88	4.48	54.5	29.2	17.9	92.0	5.4	5.3
SEm±	0.05	0.05	0.10	0.07	2.23	0.69	0.40	1.04	0.22	0.26
CD (P=0.05)	0.10	0.12	0.22	0.15	4.55	1.41	0.83	2.14	0.46	0.53
Sulphur										
0.0	2.75	4.23	12.85	4.04	55.7	27.1	15.8	66.7	6.1	5.8
12.5	3.37	5.28	13.03	4.17	71.4	34.9	15.9	68.9	8.2	7.9
25.0	3.59	5.52	13.56	4.30	76.6	37.6	15.0	63.9	9.8	9.2
50.0	3.14	5.10	13.69	4.33	68.3	35.0	11.2	52.7	9.0	8.9
SEm±	0.05	0.05	0.10	0.07	2.23	0.69	0.40	1.04	0.22	0.26
CD (P=0.05)	0.10	0.12	0.22	0.15	4.55	1.41	0.83	2.14	0.46	0.53

observed owing to less grain and straw yield due to its toxicity. An increase in Cd uptake by its application has been reported by Dahiya et al. (1987). Increasing levels of S decreased the uptake of Cd by oat from 15.8 to 11.2 mg/pot in grain and from 66.7 to 52.7 µg /pot in straw with 50 mg S kg^{-1}. The depressing effect of S on Cd may be attributed to the formation of insoluble cadmium sulphide compounds in soil and thereby restricting its mobilization and transport with in the plant. Thus, S addition appears to have a beneficial effect in checking the toxic effect of Cd in oat. The uptake of S by oat grain and straw decreased significantly by the addition of Cd. Decreased S uptake might be due to decreased plant growth at higher levels of Cd which resulted in less absorption and accumulation of S by the crop.

References

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