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**Journal of Farming Systems Research and Development**

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## CONTENTS

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# EFFECT OF CHEMICAL WEED CONTROL ON WEEDS, WHEAT PRODUCTIVITY AND PROFITABILITY IN RICE-WHEAT CROPPING SYSTEM IN MID WESTERN PLAIN ZONE OF UTTAR PRADESH

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## ABSTRACT

A field experiment was conducted at the Farm of *Krishi Vigyan Kendra, Budaun* during three consecutive *Rabi* seasons of 2008-09 to 2010-11. The experiment was conducted in Randomized Block Design with 4 weed control treatments *viz.*, Weedy check, Isoproturon (1.0 kg $ha^{-1}$), Sulfosulfuron (0.034 kg $ha^{-1}$) and Clodinofop propargyl (0.600 kg $ha^{-1}$) replicated five times. The soil of the experimental field was sandy loam in texture, with pH 7.8 and was low in organic carbon (0.23%) and medium in available phosphorus (34 kg $P_2O_5$ $ha^{-1}$) and low in available potassium (124 kg $ha^{-1}$). A uniform dose 60 kg N, 60 kg $P_2O_5$ and 60 kg $K_2O$ $ha^{-1}$ was applied at the time of sowing and remaining 60 kg N was top dressed in two splits after first irrigation and maximum tillering stage. Wheat variety PBW 550 was sown in the second week of November during all the years using seed rate of 100 kg $ha^{-1}$. All the post-emergence herbicides were applied at 30 days after sowing by flat fan nozzle hand sprayer with spray volume 500 litres of water $ha^{-1}$. The results showed that all herbicidal treatments significantly reduced density and dry matter of weeds at 90 DAS compared to weedy check with maximum reduction by clodinofop propargyl followed by sulfosulfuron and isoproturon along with 79.01, 77.73 and 66.23 per cent weed control efficiency, respectively. Clodinofop propargyl being at par with sulfosulfuron, isoproturon produced highest and significantly more ears/$m^2$ (357), grain (43.21 q $ha^{-1}$) and straw (55.02 q$ha^{-1}$) yields as compared to weedy check (298 ears/$m^2$, 37.46 and 45.56 q $ha^{-1}$ grain and straw yields, respectively). Maximum net returns (Rs. 41744 $ha^{-1}$) and benefit cost ratio (3.35) was recorded with the application of clodinofop propargyl followed by sulfosulfuron (39118 and 3.24) and isoproturon (36320 and 3.15) with lowest under weedy check (32368 and 2.84), respectively.

**Key words:** Clodinofop propargyl, Herbicides, Isoproturon, Productivity, Profitability, Significantly, Square root transformation, Sulfosulfuron, Weed control efficiency, Weedy check, Weeds, Wheat.

Wheat belongs to family "Graminae" and genus "Triticum". Among the food crops, wheat is one of the most important cereals of the world and it is grown extensively throughout the world. In India, it is most important winter cereal, contributing approximately 30-35 per cent to total food grain production. It occupies 29.9 million hectare area with production of 93.9 million tonnes with average productivity of 31.40 quintal per hectare in the year 2011-12 which is low as compared to many countries (Economic Survey, 2012). It plays an important role in the food economy and food security system of the country. The requirement of wheat will be around 109 million tonnes for feeding the deeming

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1.25 billion populations by 2020 AD (Singh, 2010). India's per capita production is 67kg against per capita consumption of 73kg, which is also on upswing. Thus, wheat production has to increase by another 15 million tonnes. There is no scope for area expansion, additional production has to come by increasing the per hectare productivity (Nagarajan, 1997) and there is need to increase the productivity to feed the growing population.

There are several constraints for low productivity of wheat in India, out of these, weeds have been recognized as an important one. Weeds are some of the major concerns in the rice–wheat system and these factors cause significant annual regional productivity losses in wheat (Harrington *et al.*, 1992). Wheat is generally infested by both grassy as well as broad-leaved weeds, but in this region grassy weeds like *Phalaris minor Retz.*, (littleseed canarygrass, Gullidanda, Mandusi, Bandriya, Gaihon ka mama); *Avena fatua* L. (Jangli Jai); *Cynodon dactylon* L. *Pers.* (Doob grass, Chibhar) are predominant weeds. Among broadleaf weeds *Convolvulus arvensis* L. (Hiran khuri); *Cirsium arvense* (L.) *Scop.; Chenopodium album* L. (Bathuwa, Bathu, Jhil); *Argemone maxicana* (Satyanasi, Katili); *Amaranthus viridis* L.(Chaulai, Mariro); *Chenopodium murale* L. (Khartuwa, Kurand, Jangli bathwa); *Melilotus alba* (Sanjani) weeds are common in this region. Monocot weeds especially little seed canary grass is highly competitive weeds and can cause drastic yield reduction under heavy infestation. The yield reduction by weeds in wheat may be up to 80% depending upon weed type, density, timing of emergence, wheat density, wheat cultivar and soil and environmental factors (Chhokar and Malik, 2002). Besides reduction in yield and quality of wheat, heavy little seed canary grass populations thus causing crop lodging.

Therefore, the control of weeds from the crop fields is essential for obtaining maximum returns. There are various methods for control of weeds including mechanical, cultural, chemical and biological methods. Out of these methods chemical weed control method is chief and easy for weed control in wheat in Indian conditions. Chemical method of weed control includes use of suitable chemicals called herbicides to kill the weeds without adversely affecting the crop. Chemical weed control is a preferred practice in wheat due to scarce and costly labour as well as lesser feasibility of manual weeding in broadcast sown wheat.

Several reports had found that *Phalaris minor* is not control effectively with isoproturon in northern Indian plains (Chhokar and Malik, 2002), therefore two other herbicides namely sulfosulfuron and clodinafop propargyl have been found effective (Chhokar *et al.* 2008). Among these, clodinafop only control the grass weeds but sulfosulfuron controls many broad-leaved weeds also (Chhokar and Malik 2002; Chhokar *et al.*, 2006). For sustaining wheat productivity, its control is essential. Keeping these facts into consideration the present investigation entitled "Effect of herbicidal weed management practices on weeds, wheat productivity and profitability in rice-wheat cropping system in Mid Western Plain Zone of Uttar Pradesh" was proposed.

## MATERIALS AND METHODS

The field experiments were conducted at the Farm of *Krishi Vigyan Kendra, Budaun* (Sardar Vallabhbhai Patel University of Agricultural & Technology, Meerut) during three consecutive *Rabi* seasons of 2008-09 to 2010-11. The experiment was conducted in Randomized Block Design with 4 weed control treatments *viz.*, weedy check (unweeded control), isoproturon (1.0 kg $ha^{-1}$), sulfosulfuron (0.034 kg $ha^{-1}$) and clodinofop propargyl (0.600 kg $ha^{-1}$) replicated five times.

The soil of the experimental field was sandy loam in texture, with slightly alkaline in reaction (pH 7.8) and was low in organic carbon (0.23%) and medium in available phosphorus (34 kg $P_2O_5$ $ha^{-1}$) and low in available potassium (124 kg $ha^{-1}$). A uniform dose 60 kg N, 60 kg $P_2O_5$ and 60 kg $K_2O$ $ha^{-1}$ was applied at the time of sowing and remaining 60 kg N was top dressed in two splits after first irrigation and maximum tillering stage. Wheat variety PBW 550 was sown in the second week of November during all the years using the seed rate of 100 kg $ha^{-1}$. The preceding crop was paddy in all the years of investigation and in this region the rice-wheat is the pre-dominant cropping system. All the post-emergence herbicides were applied at 30 days after sowing. The quantity of spray volume was calculated by test run and the herbicides were applied with flat fan nozzle hand sprayer. Herbicide spray volume was 500 litres water $ha^{-1}$. The crop was irrigated six times at 20, 40, 60, 80, 100 and 120 days after sowing during all the years.

Data on density and dry matter weight were recorded at 90 days after sowing (DAS) from each plot in two quadrates, each of 1 x 1m area. Weeds were counted as monocots and dicots and then removed them for obtaining their dry weight. Weed samples were first sun dried and then over dried until constant weight obtained. Data on weed density were subjected to square root transformation $\sqrt{X+0.5}$ to normalize their distribution before statistical analysis. Weed control efficiency was calculated with the formula suggested by as Kumar *et al.* (2012). Crop was harvested manually in third week of April during all the years of investigation. Data on yield attributes and yield were recorded using standard techniques and subjected for statistical analysis.

## RESULTS AND DISCUSSION

### Effect on weeds

Among the total weed flora as observed from the unweeded control plots consisted of 72.25 and 27.75 per cent monocot and dicot weeds, respectively. Data (Table 1) showed that all the herbicidal treatments significantly reduced density and dry matter of weeds compared to unweeded control. Maximum reduction in density and dry matter of total weeds was recorded with the spray of clodinofop propargyl followed by sulfosulfuron and isoproturon in all the years of experimentation. Application of clodinofop propargyl being at par with sulfosulfuron but significantly reduced the density and dry matter of monocot weeds at 90 DAS of crop as compares to unweeded control and isoproturon, unable to reduce the density and dry matter of dicot weeds up to significant level. However, clodinofop significantly reduced the density ($6.85/m^2$) and dry matter ($28.53 g/m^2$) of total weeds as compared to unweeded control ($13.24/m^2$ and $135.9 g/m^2$, respectively). Further,

**Table 1. Effect of different chemical weed control treatments on density and dry matter of weeds and weed control efficiency in wheat at 90 DAS (Average of 03 years)**

| Treatment | Dose (kg/ha) | Weed density (No./$m^2$) | | | Dry matter of weeds (g/$m^2$) | | | Weed control efficiency (%) |
|---|---|---|---|---|---|---|---|---|
| | | Monocots | Dicots | Total | Monocots | Dicots | Total | |
| Unweeded check | - | 11.26 (126.3) | 7.00 (48.5) | 13.24 (174.8) | 103.30 | 32.60 | 135.90 | - |
| Isoproturon | 1.000 | 5.85 (33.7) | 5.63 (31.2) | 8.09 (64.9) | 26.50 | 19.40 | 45.90 | 66.23 |
| Sulfosulfuron | 0.034 | 4.66 (21.2) | 5.17 (26.2) | 6.92 (47.4) | 12.97 | 17.30 | 30.27 | 77.73 |
| Clodinofop propargyl | 0.600 | 1.84 (2.9) | 6.63 (43.5) | 6.85 (46.4) | 2.13 | 26.45 | 28.53 | 79.01 |
| CD (P=0.05) | - | 2.96 | 1.81 | 2.32 | 14.07 | 8.98 | 16.39 | |

*Figures in parentheses are original values, Data were square root transformed before analysis through $=\sqrt{X+0.5}$

sulfosulfuron spray also reduced significantly the density and dry matter of all categories of weeds at 90 DAS as compares to unweeded control. Similarly, isoproturon also reduced the density and dry matter of weeds at 90 DAS as compares to unweeded control except density of dicot weeds. The average weed control efficiency (WCE) was 79.01, 77.73 and 66.23 per cent with the application of clodinofop propargyl, sulfosulfuron and isoproturon, respectively. This was mainly due to effective control of weeds during early growth stage of the crop especially monocot weeds, although dicot weeds also controlled by sulfosulfuron and isoproturon. These results are in conformity of Chhokar *et al.* (2007), Kumar and Jat (2008) and Bharat *et al.* (2012)

## Effect on wheat yield attributes

The results (Table 2) showed that the yield attributes of wheat were significantly influenced due to application of different herbicides viz, clodinofop propargyl, sulfosulfuron and isoproturon as compared to unweeded control. All the herbicides produced significantly higher number of effective ears/$m^2$ as compared to unweeded control, however all the herbicides remained at par with each other. Though higher values of grains/ear and 1000 grain weight were also recorded with the application of herbicides but could not reach up to significant level over unweeded control. Maximum values of yield attributes i.e. effective ears/$m^2$ (357), grains/ear (42.84) and 1000 grain weight (44.86 g) were recorded with the application of clodinofop propargyl followed by sulfosulfuron and isoproturon with minimum in unweeded plots during all the years of experimentation. This is due to minimum crop weed competition with these herbicidal treatments enabled the crop plant to make maximum use of available dry matter for the formation and development of yield attributes. These

**Table 2. Effect of different chemical weed control treatments on yield attributes, yield and economics of wheat (Average of 03 years)**

| Treatment | Dose (kg/ha) | Effective Ears/m$^2$ | Grains/ ear | 1000 grain weight (g) | Grain yield (q ha$^{-1}$) | Straw yield (q ha$^{-1}$) | Net return (Rs ha$^{-1}$) | B:C Ratio |
|---|---|---|---|---|---|---|---|---|
| Unweeded check | - | 298 | 40.20 | 41.96 | 37.46 | 45.56 | 32368 | 2.84 |
| Isoproturon | 1.000 | 332 | 41.60 | 43.61 | 40.98 | 51.25 | 36320 | 3.15 |
| Sulfosulfuron | 0.034 | 349 | 42.03 | 44.27 | 42.84 | 53.67 | 39118 | 3.24 |
| Clodinofop propargyl | 0.600 | 357 | 42.84 | 44.86 | 43.21 | 55.02 | 41744 | 3.35 |
| CD (P=0.05) | - | 26.2 | NS | NS | 2.97 | 3.89 | - | - |

facts are consistent with the findings of Kumar and Jat (2008), Punia and Yadav (2009).

## Effect on wheat productivity

The data in the Table 2 indicated that grain and straw yields of wheat were influenced significantly due to application of different herbicides. Application of clodinofop propargyl being at par with sulfosulfuron and isoproturon but produced maximum and significantly higher grain (43.21 q ha$^{-1}$) and straw (55.02 qha$^{-1}$) yields as compared to unweeded control (37.46 and 45.56 q ha$^{-1}$ grain and straw yields, respectively). Further, sulfosulfuron and isoproturon also produced significantly higher grain (42.84 and 40.98 q ha$^{-1}$) and straw (53.67 and 51.25 qha$^{-1}$) yields as compared to weedy control. The increment in yield is mainly due to better control of weeds under the herbicidal weed control treatments which provided better environment for growth and development of the crop and ultimately resulted in improved yield of the crop. Similar findings were also reported by Chhokar *et al.* (2007), Kumar and Jat (2008) and Bharat *et al.* (2012).

## Effect on wheat profitability

The data (Table 2) showed that application of herbicides resulted in marked economic advantage over unweeded control. Maximum net returns (Rs. 41744 ha$^{-1}$) and benefit cost ratio (3.35) was recorded with the application of clodinofop propargyl followed by sulfosulfuron (39118 and 3.24) and isoproturon (36320 and 3.15) with lowest under unweeded control (32368 and 2.84), respectively. The higher and equal benefit cost ratios under herbicidal weed management was owing to more grain yield. These results are in conformity with the study of Kumar and Jat (2008).

On the basis of three years study it can be concluded that weed control by new herbicides is the easy and economical method of weed control in the early growth stage of wheat for crop growth and development of crop resulted in higher productive and profitability.

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*J. Farming Systems Research & Development* **21** (1) : 7-11 (2015)

# PERFORMANCE OF CHICKPEA GENOTYPES AND POD BORER INCIDENCE UNDER DOON VALLEY CONDITIONS OF UTTARAKHAND

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## ABSTRACT

A field experiment was conducted during winter (*rabi*) seasons of 2008-2009 and 2009-2010 at Research Farm of GBPUA&T-K.V.K. & Horticulture Research & Extension Centre, Dhakrani, Dehradun, Uttarakhand to study the performance of various chickpea genotypes and the incidence of pod borer under Doon valley conditions. Highest grain yield was recorded with the genotype KPG 59 (1668 kg $ha^{-1}$). Genotype PG 186 recorded least damage to the pods (12.3 and 15.1 per cent during 2008-2009 and 2009-2010, respectively), while the genotype PG 114 had the maximum damage due to pod borer (24.7 and 27.4 percent during 2008-2009 and 2009-2010, respectively).

**Keywords:** Chickpea, genotypes, grain yield, pod borer incidence

Chickpea (*Cicer arietinum L.*) is the third most important pulse crop in the world after beans (*Phaseolus vulgaris*) and peas (*Pisum sativum*). But its poor productivity makes it non competitive in comparision to present day high yielding varieties of cereals. In India chickpea is the leading pulse crop. It is grown on 6.72 million hectare area with annual production of 5.47 million tones and average productivity of 815 kg/ha (FAI 2006).

Pod borer is the major limiting factor in achieving the higher productivity of chickpea. It is a devastating pest of gram, which remains active from the vegetative stage to maturity stage, however, incidence of pod borer at pod formation stage resulted in maximum yield loss. It has developed resistance against most of the insecticides, therefore, till date not nevertheless insecticides have been recommended for its control (Mehrotra, 1991). Genotypes resistant against pod borer may play an important role for integrated pest management in gram, hence, the present experiment was conducted to study the performance of various chickpea genotypes and the incidence of pod borer under Doon valley conditions.

## MATERIALS AND METHOD

A field experiment were conducted during winter (*rabi*) seasons of 2008-2009 and 2009-2010 at Research Farm of GBPUA&T-K.V.K. & Horticulture Research & Extension Centre, Dhakrani, Dehradun, Uttarakhand (at 77’ 42" East, 30’ 26" North and 1409 foot above sea level) to study the performance of various chickpea genotypes and the incidence of pod borer in these chickpea genotypes under Doon valley conditions. The soil under the experiment was well drained, sandy loam in texture, poor in organic carbon (0.47 %), low in available nitrogen (265 kg $ha^{-1}$), high in available

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phosphorus (30 kg ha$^{-1}$) and medium in available potassium (132 kg ha$^{-1}$). The pH value of soil of experimental site was 5.7. Six treatments comprising of six genotypes viz PG 114, PG 186, Avrodhi, Pusa 256, KPG 59 and local was laid out in randomized block design with four replications. The recommended package and practices were followed for the crop with no control measures were taken for the insect-pests control. The data on various growth parameters, yield attributing characters, grain and biological yield and pod borer incidence were recorded and analyses statistically.

## RESULTS AND DISCUSSION

### Performance of different chickpea genotypes

Data given in table 3 shows that genotype KPG 59 produced significantly higher grain yield (1194 and 2143 kg/ha during I$^{st}$ year and II$^{nd}$ year, respectively) than rest of the genotypes. However, in second year it was statically at par with Pusa 256. The lowest grain yield of 1020 kg/ha during Ist year and 1404 kg/ha during II$^{nd}$ year was recorded with PG 114. On the basis of pooled analysis, significantly highest grain yield was recorded with the genotype KPG 59 (1668 kg ha$^{-1}$) compared to rest of the genotypes followed by PG186 (1420 kg/ ha). However, it was statistically at par with Pusa 256 (1537 kg ha$^{-1}$). Genotype PG 114 recorded significantly lowest grain yield (1212 kg ha$^{-1}$).

Higher yield in KPG 59 may be due to significantly improved growth and yield attributing character under this genotype (Table 1&2).

During the year 2008-09 local cultivar produced highest biological yield (4553 kg ha$^{-1}$) and it was higher than those of PG 114, PG 186 and Pusa 256. During the next year (2009-10) highest biological yield (7080 kg ha$^{-1}$) was recorded with KPG 59, it was at par with Local and significantly higher than those of PG 114 and Avrodhi. On the basis of pooled data of two years, highest biological yield (5769 kg ha$^{-1}$) was recorded with KPG 59 which was at par with local and significantly superior than rest of the genotypes.

Genotype KPG 59 and local cultivar took least time (86 days) to come to the fifty percent flowering, while Pusa 256 took maximum time (93 days) to come to

**Table 1. Growth parameters of different gram genotypes (pooled data of two years).**

| Genotype | Days to 50 per cent flowering | Maturity in days | Plant height at 50 % flowering | Number of primary branches/ plant | Crop Growth Rate (Dry matter(g)/ day) |
|---|---|---|---|---|---|
| PG 114 | 89 | 141 | 56.1 | 3.5 | 0.15 |
| PG 186 | 89 | 130 | 56.4 | 3.3 | 0.18 |
| Avrodhi | 88 | 150 | 56.6 | 3.3 | 0.16 |
| Pusa 256 | 93 | 147 | 57.3 | 3.6 | 0.16 |
| KPG 59 | 86 | 139 | 56.3 | 3.9 | 0.19 |
| Local | 86 | 143 | 57.7 | 4.0 | 0.17 |
| CD 5 % | 1.2 | 2.0 | 1.69 | 0.28 | - |

**Table 2. Yield attributing characters of different gram genotypes.**

| Genotype | Number of pods/plant | | | Number of grains/pod | | | 100 seed weight (gram) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2008-09 | 2009-10 | Pooled | 2008-09 | 2009-10 | Pooled | 2008-09 | 2009-10 | Pooled |
| PG 114 | 24.3 | 26.4 | 25.3 | 0.8 | 0.8 | 0.8 | 13.8 | 13.6 | 13.7 |
| PG 186 | 27.3 | 25.3 | 26.3 | 1.1 | 1.1 | 1.1 | 16.0 | 15.9 | 16.0 |
| Avrodhi | 25.1 | 27.4 | 26.2 | 1.0 | 1.0 | 1.0 | 15.8 | 15.9 | 15.8 |
| Pusa 256 | 22.8 | 45.3 | 34.0 | 1.1 | 1.1 | 1.1 | 16.4 | 16.1 | 16.2 |
| KPG 59 | 25.9 | 40.7 | 33.3 | 1.1 | 1.1 | 1.1 | 16.0 | 15.8 | 15.9 |
| Local | 24.9 | 38.7 | 31.8 | 1.4 | 1.4 | 1.4 | 14.8 | 15.3 | 15.0 |
| CD 5 % | 3.48 | 3.86 | 2.06 | 0.07 | 0.03 | 0.04 | 0.67 | 0.23 | 0.33 |

**Table 3. Grain and biological yield of different gram genotypes**

| Genotype | Grain yield | | | Biological yield | | |
|---|---|---|---|---|---|---|
| | 2008-09 | 2009-10 | Pooled | 2008-09 | 2009-10 | Pooled |
| PG 114 | 1020 | 1404 | 1212 | 3645 | 5748 | 4696 |
| PG 186 | 1110 | 1730 | 1420 | 4033 | 6408 | 5220 |
| Avrodhi | 1124 | 1573 | 1348 | 4385 | 6038 | 5211 |
| Pusa 256 | 1042 | 2031 | 1537 | 3860 | 6498 | 5179 |
| KPG 59 | 1194 | 2143 | 1668 | 4458 | 7080 | 5769 |
| Local | 1160 | 1555 | 1358 | 4553 | 6168 | 5310 |
| CD 5 % | 123.4 | 186.2 | 132.4 | 316.6 | 924.6 | 472.8 |

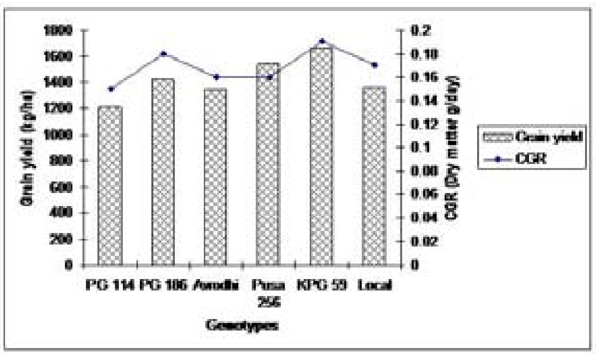


**Fig. 1. Grain yield and crop growth rate of different genotypes**

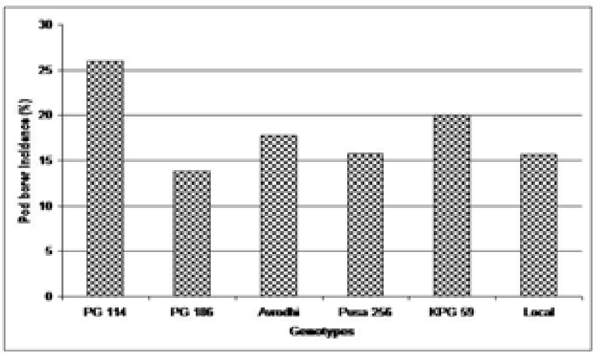


**Fig. 2. Incidence of pod borer in different genotypes**

this stage. The longest maturity period (150 days) was recorded with the Avrodhi genotype and reverse was found in case of PG 186 which was taken 130 days to come to maturity. Highest plant height was recorded with local (57.7 cm) and it was statistically at par with the rest of the genotypes. Highest crop growth rate of 0.19 g per day was recorded with the genotype KPG 59, while it was recorded lowest 0.15 g per day with PG 114. On the basis of pooled data highest number of pods per plant (34.0) was recorded with Pusa 256 followed by KPG 59 (33.3) and these two genotypes produced significantly higher number of pods than the remaining genotypes. Ramesha and Jain (2006), Berger and Turner (2002), and Singh (1986) also reported the positive relationship between yield, yield attributing and growth parameters of various genotypes.

## Incidence of chickpea pod borer on different genotypes

During the year 2008-09, the incidence of chickpea pod borer varied from 12.3 to 24.7 per cent. Genotype PG 186 had the lowest damage due to pod borer (12.3 per cent) which was significantly lower than those in PG 114 (24.7 per cent), Avrodhi (15.4 per cent) and KPG 59 (18.4 per cent). PG 186 was at par with Pusa 256 (14.5 per cent) and local cultivar (14.1 per cent) for the pod borer incidence. Same trend was true for the next year (2009-10) too, during this year incidence of chickpea pod borer varied from 15.1 to 27.4 per cent. Here, again genotype PG 186 had the lowest incidence (15.1 per cent) of pod borer and it was significantly lower than those in PG 114 (27.4 per cent), Avrodhi ( 20.0 per cent) and KPG 59 ( 21.7 per cent). Genotype PG 186 was at par with Pusa 256 (17.0 per cent) and local cultivar (17.2 per cent) for the incidence of pod borer damage.

**Table 4. Incidence of pod borer in different gram genotypes.**

| Genotype | Damaged pods (%) | | |
|---|---|---|---|
| | 2008-09 | 2009-10 | Pooled |
| PG 114 | 24.7 | 27.4 | 26.0 |
| PG 186 | 12.3 | 15.1 | 13.7 |
| Avrodhi | 15.4 | 20.0 | 17.7 |
| Pusa 256 | 14.5 | 17.0 | 15.7 |
| KPG 59 | 18.4 | 21.7 | 20.0 |
| Local | 14.1 | 17.2 | 15.6 |
| CD 5 % | 3.0 | 2.7 | 1.8 |

On the basis of analysis of pooled data of both the years, genotype PG 186 had the lowest pod borer damage (13.7 per cent) which was significantly lower than those in the remining genotypes. Genotype PG 114 had the highest damage (26.0 per cent) due to pod borer, which was significantly higher than those in remaining genotypes. Different genotypes can be arranged for the pod borer incidence in ascending order like this PG 186 (13.7 per cent) < Local (15.6 per cent) < Pusa 256 (15.7 per cent) < KPG 59 (20.0 per cent) < PG 114 (26.0 per cent).

However, under Doon Valley conditions 20 per cent pods of KPG 59 were damaged by the pod borer, still this genotype could be preferred over the other genotypes, as this genotype recorded the highest grain yield (1668 kg/ha) (pooled data) without any control measures taken for the pod borer damage.

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# INFLUENCE OF ENVIRONMENTAL FACTORS ON THE POPULATION DYNAMICS AND INFESTATION PATTERN OF *LEUCINODES ORBONALIS* IN WINTER BRINJAL UNDER NORTH CENTRAL PLATEAU ZONE OF ODISHA

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## Abstract

The population dynamics and infestation pattern of brinjal shoot and fruit borer (BSFB) *Leucinodes orbonalis* Guenee in relation to different environmental factors was studied during the winter seasons of 2009-10 and 2010-11 at Keonjhar, Odisha. The maximum adult activity was noticed during 50$^{th}$ and 7$^{th}$ SW in 2009-10 and during 48$^{th}$ and 7$^{th}$ SW in 2010-11, whereas, the highest larval population of BSFB was observed one week after the maximum adult activity in each case. The pest infestation on shoots started from the second fortnight of October in both the years and the peak shoot infestation was observed during 47$^{th}$ and 49$^{th}$ SW in 2009-10 and 2010-11, respectively. However, the peak infestation on flower buds and fruits occurred during 51$^{st}$ and 8$^{th}$ SW in 2009-10 and on 49$^{th}$ and 8$^{th}$ SW during 2010-11. From the correlation study it was observed that temperature factors exerted a positive influence and relative humidity had a negative effect on the population build up and infestation of the pest. The findings of the investigation also indicated that among the abiotic factors temperature and relative humidity had maximum contribution towards the fluctuation in pest incidence and infestation.

**Key words:** Brinjal, *Leucinodes orbonalis*, seasonal incidence, weather variable

## Introduction

Brinjal shoot and fruit borer (BSFB is the most prevalent and highly destructive insect pest of brinjal in the South and South East Asian countries and is widely distributed in the Indian subcontinent causing considerable yield and economic loss. This pest causes serious crop losses ranging from 15-70% in all the brinjal producing areas of the world (Sandanayake and Edirisinghe, 1992) and the apparent losses of fruits have been reported to be varying from 20-90 % in various parts of India (Raju *et al.*, 2007). Being an internal borer the early instar larvae of this pest feed exclusively on the tender shoots, petiole and flower buds, while the later instars bore into the fruits. Exclusive reliance of chemical pesticides for managing this pest has been proving ineffective owing to its feeding pattern and ability to develop resistance against many insecticides. Hence, information on the seasonal variation in the population level and infestation pattern and the peak period of population build up is highly important in deciding the appropriate time of deliberate plant protection measures. Pheromone traps are now effectively used to monitor the seasonal abundance of BSFB in many parts of the country (Tiwari *et al.*, 2009). As, various environmental factors influence the seasonal variation in the population dynamics and infestation pattern, it is essential to study their relationship to develop location specific management strategies. Hence, in the present investigation attempts were made to monitor the population build up of BSFB and its infestation patterns.

## Materials and Methods

The experiments were carried out in the instructional farm of Krishi Vigyan Kendra, Keonjhar, Odisha during the winter seasons of 2009-10 and 2010-11. The brinjal crops (variety Blue Star) were raised in well prepared plots with all the recommended agronomic package of practices and intercultural operations to ensure optimum plant growth. No plant protection measures were taken up to encourage natural population build up of BSFB and its infestation on different plant parts. The seasonal incidence of the pest was studied from the pheromone traps installed in the trial plots and the trap catches of male adults were expressed as number of males trapped per trap per week. In each plot five numbers of pheromone traps (funnel trap) were installed at 5 m interval ensuring the lure position just above the crop canopy. Week wise larval population of BSFB from all sources *viz*. shoot, flower bud and fruit was recorded as average number of larvae/ plant/week from 10 randomly selected plants from the initiation of damage and expressed as larval intensity. Similarly, BSFB infestation on shoots, flower buds and fruits were recorded in weekly basis from 10 randomly selected plants right from the initiation of pest damage and continued till harvesting of the crop. The per cent infestation was worked on the basis of number of healthy and damaged plant parts. The environmental parameters like maximum temperature, minimum temperature, relative humidity (morning and evening) and rainfall were collected from the meteorological observatory of Regional Research and Technology Transfer Station, Keonjhar for the corresponding period of investigation to find out the effect of various abiotic factors on the population dynamics and infestation of BSFB. The abiotic factors were subjected to multiple correlation analysis with trap catch, larval intensity and damaged plant parts to know their relationship whereas regression analysis was taken up to ascertain the contribution of each abiotic factor on the population level and damage. In all the cases of analysis, the abiotic factors prevailed during the previous standard week were correlated and regressed with the damage level recorded in the succeeding week.

## Result and Discussion

### Seasonal variation in the population build up and infestation of BSFB:\

The adult moth activity of BSFB was initiated during $41^{st}$ SW ($2^{nd}$ week of October) and was active up to $11^{th}$ SW ($2^{nd}$ week of March) in both the years of study with two distinct peak population level (Table 1 and Fig.1). The first peak was attained during $50^{th}$ and $48^{th}$ SW, respectively for 2009-10 and 2010-11 and after a gradual decline in population level, the second peak was observed during $7^{th}$ SW in both the years. The maximum larval population was observed one week after the peak adult trap catch in both the years of experiment. The present findings are in harmony with Varma *et al.* (2009) who observed that maximum population of *L. orbonalis* during rabi season prevailed during $2^{nd}$ to $4^{th}$ week of December. BSFB infestation on brinjal shoots commenced from $43^{rd}$ SW in 2009-10 and $42^{nd}$ SW in 2010-11 and exhibited an upward trend to attain the peak infestation level during $47^{th}$ and $49^{th}$ SW with 27.28 and 30.55 % shoot damage, respectively in 2009-10 and 2010-11 (Table 1 and Figure 2). From December onwards the shoot infestation gradually declined to reach lower level

**Table 1. Seasonal fluctuation in abundance and infestation of BSFB during winter 2009-10 and 2010-11**

| S. W | Pheromone trap catch (No./trap/weak) | | Larval Intensity (No/plant/weak) | | Shoot damage (%) | | Flower bud damage (%) | | Fruit damage (%) (number basis) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2009-10 | 2010-11 | 2009-10 | 2010-11 | 2009-10 | 2010-11 | 2009-10 | 2010-11 | 2009-10 | 2010-11 |
| 40 | | | | | | | | | | |
| 41 | 2.20 | 3.20 | | | | | | | | |
| 42 | 3.40 | 2.80 | | 0.40 | | 10.33 | | | | |
| 43 | 2.80 | 2.60 | 0.60 | 0.50 | 11.86 | 14.28 | | | | |
| 44 | 2.20 | 2.20 | 0.60 | 0.70 | 11.33 | 15.87 | 6.86 | 11.56 | | |
| 45 | 3.20 | 2.40 | 1.10 | 0.70 | 19.36 | 14.38 | 11.23 | 10.38 | | |
| 46 | 3.40 | 3.20 | 1.40 | 1.20 | 25.24 | 19.59 | 17.56 | 15.34 | 10.29 | 12.29 |
| 47 | 3.60 | 4.20 | 1.50 | 1.40 | 27.28 | 23.25 | 19.45 | 21.33 | 19.37 | 19.25 |
| 48 | 2.60 | 5.00 | 1.20 | 1.70 | 20.58 | 28.28 | 15.68 | 25.29 | 14.38 | 24.86 |
| 49 | 3.40 | 4.60 | 1.60 | 1.90 | 21.32 | 30.55 | 18.33 | 26.35 | 21.26 | 29.36 |
| 50 | 5.40 | 2.80 | 1.90 | 1.30 | 23.58 | 19.24 | 24.46 | 17.26 | 29.25 | 25.28 |
| 51 | 5.20 | 3.60 | 2.10 | 1.60 | 22.26 | 21.58 | 30.28 | 22.34 | 35.28 | 27.65 |
| 52 | 4.80 | 3.20 | 1.90 | 1.30 | 20.48 | 17.36 | 26.74 | 20.27 | 29.24 | 23.33 |
| 1 | 3.20 | 3.80 | 1.60 | 1.50 | 16.72 | 18.33 | 20.55 | 25.52 | 25.48 | 27.28 |
| 2 | 3.20 | 3.00 | 1.50 | 1.30 | 15.46 | 14.28 | 20.28 | 19.36 | 26.28 | 22.24 |
| 3 | 3.80 | 3.80 | 1.80 | 1.50 | 19.24 | 16.56 | 25.76 | 23.35 | 29.32 | 26.52 |
| 4 | 3.20 | 4.40 | 1.50 | 1.70 | 14.58 | 19.27 | 21.68 | 25.24 | 27.56 | 29.56 |
| 5 | 4.20 | 5.20 | 1.90 | 2.00 | 16.32 | 19.52 | 26.32 | 28.58 | 31.85 | 32.38 |
| 6 | 4.80 | 5.20 | 1.90 | 2.10 | 18.86 | 17.58 | 28.66 | 31.53 | 33.33 | 34.33 |
| 7 | 6.00 | 6.20 | 2.10 | 2.40 | 21.64 | 18.24 | 34.45 | 32.58 | 38.26 | 35.26 |
| 8 | 5.60 | 6.00 | 2.30 | 2.60 | 22.32 | 21.39 | 36.26 | 35.39 | 41.46 | 39.74 |
| 9 | 5.20 | 5.20 | 2.00 | 2.10 | 23.32 | 17.52 | 34.47 | 27.52 | 36.38 | 29.38 |
| 10 | 5.40 | 4.80 | 2.10 | 2.10 | 19.29 | 18.38 | 24.39 | 28.64 | 32.54 | 30.38 |
| 11 | 4.80 | 4.20 | 1.80 | 1.90 | 12.74 | 14.79 | 18.28 | 19.28 | 27.28 | 28.52 |

S.W- Standard week

towards the end of the cropping season. The findings of Sasmal (1997) appears to be in close conformity with the present investigation as he reported that maximum shoot damage was attained during last week of October to first week of November in Bhubaneswar condition. The pest infestation on flower buds initiated during $44^{th}$ SW in both the years of study with two distinct peak infestation levels. In 2009-10, the first peak flower bud damage occurred during $51^{st}$ SW with an infestation level of 30.28 % and the subsequent peak was attained at $8^{th}$ SW with flower bud infestation of 36.26 per cent. In 2010-11, almost similar trend of flower bud damage was observed with the first peak at $49^{th}$ SW and the second peak at $8^{th}$ SW having 26.35 and 35.39 % flower bud infestation, respectively. Samal (2008) also reported in the same line and mentioned that the peak larval incidence in flower buds (33 %) was recorded during $6^{th}$ SW i.e. $2^{nd}$ week of February. The fruit damage by the test insect was marked in $46^{th}$ SW in both 2009-10 and 2010-11 with two peak infestation stages. In 2009-10 the first peak was at $51^{st}$ SW with 35.28 % fruit damage (on number basis) and that of in 2010-11 was noticed during $49^{th}$ SW with 29.36 % fruit damage. During $8^{th}$ SW in both the years, again the fruit damage reached its subsequent highest level with 41.46 and 39.74 % damage in 2009-10 and 20100-11, respectively.

## Correlation of environmental factors with the population build up and infestation of BSFB

In both the years of experiment maximum temperature showed a significant positive relationship with the pheromone trap catch (r = 0.430 and 0.511, respectively) (Table 2). While minimum temperature resumed negative relationship with adult trap catch, the average temperature retained positive relationship but the influence of both the abiotic factors was not much pronounced. Relative humidity (both morning and afternoon) had significant negative correlation with the pheromone trap catch during both the years of investigation (r = -0.458 to -0.692) and so was the case with rain fall, where during 2010-11, significant negative relationship was witnessed. Shukla and Khatri (2010) also observed that maximum temperature had positive correlation and relative humidity had negative correlation with the adult moth population of *L. orbonalis*. A similar trend of correlation was also observed between the environmental factors and the larval population level in both the years. However, these correlations were not statistically significant in 2009-10. But during. 2010-11, a significant positive correlation existed with maximum temperature (r =0.454) and significant negative correlation was recorded with relative humidity (r =-0.684 and -0.804, respectively for morning and afternoon) and rainfall (r = -0.453). It was revealed from Table 2 that during 2009-10 all the weather variables exhibited a positive correlation with the shoot infestation with non-significant correlation coefficient values, indicating a weak link between abiotic factors and shoot damage. However, in the subsequent year of study, the shoot infestation had a non-significant positive correlation with maximum, minimum and average temperature and non-significant negative correlation with rainfall and relative humidity. However, on the flower bud infestation, maximum and average temperature had a positive influence and minimum temperature exerted a non-significant negative

**Table 2. Correlation of weather parameters with the abundance and infestation of BSFB**

| Abiotic factors | Correlation coefficient ( r ) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Pheromone trap catch | | Larval intensity | | Shoot damage | | Flower bud damage | | Fruit damage | |
| | 2010 | 2011 | 2010 | 2011 | 2009-10 | 2010-11 | 2009-10 | 2010-11 | 2009-10 | 2010-11 |
| Maximum Temperature(° C) | 0.430 * | 0.511* | 0.162 | 0.454 * | 0.035 | 0.193 | 0.122 | 0.421 | 0.307 | 0.356 |
| Minimum Temperature(° C) | -0.086 | -0.296 | -0.094 | -0.371 | 0.029 | 0.151 | -0.056 | -0.362 | 0.021 | -0.246 |
| Average Temperature(° C) | 0.173 | 0.071 | 0.047 | 0.092 | 0.033 | 0.203 | 0.030 | 0.027 | 0.186 | 0.077 |
| Rainfall (mm) | -0.357 | -0.429 * | -0.073 | -0.453 * | 0.349 | -0.236 | -0.115 | -0.397 | -0.313 | -0.207 |
| RH ( %) (Morning) | -0.494 * | -0.616 * | -0.196 | -0.684 * | 0.008 | - 0.155 | -0.168 | -0.568* | -0.359 | -0.478* |
| RH( %) (After noon) | -0.458 * | -0.692* | -0.153 | -0.804 * | 0.123 | - 0.152 | -0.137 | -0.654* | -0.324 | -0.623 * |

* Significant at 0.05 level

influence. The relative humidity (both morning and evening) showed a non-significant negative relationship with the flower bud damage during 2009-10, but during 2010-11 such correlation was significantly negative (r = -0.568 and 0.654 for morning and evening R.H, respectively). Among the abiotic factors, maximum and average temperature had a non-significant positive effect and relative humidity (both morning and afternoon) had negative influence on fruit damage. However, during the year 2010-11 the effect of R.H on fruit damage was statistically significant (r = -0.478 and -0.623 for fruit damage on number basis and r = -0.471 and -0.615 for weight basis). The present findings also in corroboration with the findings of Ishar *et al.* (2007) who reveled that mean minimum temperature did not significantly influence the incidence of *L. orbonalis* on shoots, whereas maximum temperature had a significant positive effect on shoot damage. However, R.H (both morning and evening) and average rainfall had significant negative influence on its incidence on shoots.

**Multiple interaction of environmental factors on the abundance and infestation of BSFB**

From Table 3 it can be visualized that the contribution of all the environmental factors in the variation of pheromone trap catch was 48.0 % ($R^2$ =0.480) in 2009-10 and 64.8 % ($R^2$= 0.648) in 2010-11. However, among all the weather parameters, maximum temperature was found to exert maximum influence on the trap catch variation with 57.69 % contribution in 2009-10 and 48.93 % in the subsequent year followed by average temperature (35.12 and 23.76 %, respectively for 2009-10 and 2010-11). Similarly, the overall impact of all the weather factors on the larval intensity is

**Table 3. Multiple interaction of weather parameters on the abundance and infestation of BSFB**

| Abundance and infestation of BSFB | Coefficient of determination ($R^2$) | Prediction equation | Per cent Contribution # | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Max. Temp. (° C) | Min. Temp. (° C) | Avg. Temp. (° C) | Rainfall (mm) | RH % (Morning) | RH % (After noon) |
| Pheromone trap catch 2009-10 | 0.480 | $Y= -9.673+0.762 X_1-0.615 X_3-0.097 X_4-0.027 X_5+0.115 X_6$ | 57.69 (1.947) | - | 35.12 (-1.519) | 1.42 (-0.305) | 0.31 (-0.142) | 5.46 (0.599) |
| Pheromone trap caych 2010-11 | 0.648 | $Y= -3.313+0.533 X_1-0.386 X_3-0.014 X_4 + 0.109 X_5- 0.115 X_6$ | 48.93 (1.247) | - | 23.76 (-0.869) | 0.02 (-0.027) | 13.29 (0.650) | 14.00 (-0.667) |
| Larval Intensity 2009-10 | 0.312 | $Y= -2.660 + 0.188 X_1-0.216 X_2 -0.056 X_4-0.041 X_5+0.082 X_6$ | 43.24 (1.230) | 40.34 (-1.188) | - | 0.23 (-0.089) | 5.76 (-0.449) | 10.43 (0.604) |
| Larval Intensity 2010-11 | 0.711 | $Y= 2.567 +0.111 X_1 –0.077 X_3+ 0.008 X_4+0.006 X_5 -0.108 X_6$ | 10.97 (0.504) | - | 4.51 (-0.323) | 0.04 (0.031) | 20.51 (0.689) | 63.98 (-1.217) |
| Shoot damage (2009-10) | 0.235 | $Y= -10.481 + 0.616 X_1-0.559 X_2+-2.503 X_4-0.097 X_5+0.430 X_6$ | 30.88 (0.429) | 17.94 (-0.327) | | 29.88 (0.422) | 2.14 (-0.113) | 19.17 (0.338) |
| Shoot damage (2010-11) | 0.233 | $Y = 53.638 -2.182 X_1 + 2.666 X_3- 0.692 X_4 +0.016 X_5 -0.475 X_6$ | 38.15 (-1.304) | - | 48.02 (1.463) | 2.65 (-0.344) | 0.00 (0.003) | 11.18 (-0.706) |
| Flower bud damage (2009-10) | 0.338 | $Y= -62.312 + 3.449 X_1-3.9539 X_2- 1.170 X_4 -0.65 X_5+1.470 X_6$ | 45.36 (1.386) | 38.99 (-1.285) | - | 0.31 (-0.115) | 4.61 (-0.442) | 10.73 (0.674) |
| Flower bud damage (2010-11) | 0.521 | $Y = -28.026 +3.370 X_1- 2.871 X_3-0.289 X_4+ 0.611 X_5-0.414 X_6$ | 57.28 (1.431) | - | 30.49 (-1.044) | 0.27 (-0.099) | 8.52 (0.552) | 3.43 (-0.350) |
| Fruit damage on number basis (2009-10) | 0.490 | $Y= -27.703 +3.246 X_1- 3.802 X_2- 3.175 X_4 -0.911 X_5 + 1.371 X_6$ | 42.57 (1.303) | 36.10 (-1.200) | - | 2.42 (-0.311) | 9.33 (-0.610) | 9.58 (0.618) |
| Fruit damage on number basis (2010-11) | 0.443 | $Y= 35.556- 1.570 X_2+ 1.647 X_3+0.201 X_4 + 0.469 X_5 – 0.871 X_6$ | - | 39.78 (-0.699) | 43.78 (0.659) | 0.65 (0.050) | 3.55 (0.440) | 12.24 (-0.708) |
| Fruit damage on number basis (2009-10) | 0.453 | $Y = -22.819 +3.235 X_1- 3.870 X_2 –3.136 X_4 –0.938 X_5 + 1.43 X_6$ | 41.32 (1.261) | 36.55 (-1.186) | - | 2.31 (-0.298) | 9.64 (-0.609) | 10.18 (0.626) |
| Fruit damage on number basis (2010-11) | 0.437 | $Y = 41.982 –1.712 X_2 +1.704 X_3 +0.296 X_4 +0.464 X_5 -0.884 X_6$ | - | 33.09 (-0.721) | 26.40 (0.644) | 0.31 (0.070) | 10.75 (0.411) | 29.44 (-0.680) |

# Contribution of different abiotic factors to abundance and infestation of BSFB

(Figures in the parentheses are the standardized partial regression coefficient values, â)

Y = Pheromone trap catch

$X_1$ = Maximum Temperature (°C), $X_2$ = Minimum Temperature (°C), $X_3$ = Average Temperature (°C), $X_4$ = Rainfall (mm)

$X_5$ = Morning Relative Humidity (%), $X_6$ = Afternoon Relative Humidity (%)

found to be only 31.2 % ($R^2$ = 0.312) in 2009-10 and maximum temperature exerted major influence (43.24 %) followed by minimum temperature (40.34 %) on the larval population level. The relative humidity played some role with 10.43 % contribution from R.H (Afternoon). However, during 2010-11 the influence of climatic factors as a whole, on the larval intensity is estimated to be 71.1 % ($R^2$ = 0.711) and relative humidity imposed a maximum influence with 63.98 % contribution from RH (Afternoon) and 20.51 % contribution from RH (Morning). In contrast to the first year study, maximum temperature had only 10.97 % influence on the larval population abundance followed by average temperature (4.51 %). The multiple effect of ecological parameters on the infestation of BSFB (Table 3) indicated that all the abiotic factors had only 23.5 % ($R^2$ = 0.235) contribution on the variation in shoot damage during 2009-10 and 23.3 % ($R^2$ =0.233) during 2010-11. Among the abiotic factors, maximum contribution on the variation in shoot damage was from maximum temperature (30.88 %) followed by rainfall (29.88%), R.H (Afternoon) (19.17 %) in 2009-10. However, during 2010-11 average temperature was found to be the most important climatic factor with maximum impact (48.02 %) followed by maximum temperature (38.15 %) and R.H (morning) (11.18 %). Similarly, during 2009-10 all the abiotic factor had 33.8 % (($R^2$ = 0.338) contribution on the pattern of flower bud damage and temperature played a key role in the variation of flower bud damage with 45.36 and 38.99 % contribution from maximum and minimum temperature respectively. During 2010-11 all the weather factors when computed together showed a 52.1 % role ($R^2$ = 0.521) on the extent of flower bud infestation and maximum temperature exhibited a dominant role (57.28 %) on the flower bud damage followed by average temperature (30.49 %). The study indicated a moderate influence of all the weather parameters on the fluctuation in fruit damage and the cumulative impact was found to be 49.0 and 45.3 % for fruit damage on number and weight basis respectively during 2009-10. Individually major contribution was made by the maximum temperature (42.57 and 41.32 %) followed by minimum temperature (36.10 and 36.55 %) for fruit damage on number and weight basis, respectively. However, during, 2010-11, all the weather parameters had 44.3 and 43.7 % role on fruit damage on number and weight basis, respectively and among the independent environmental parameters, average temperature had dominant influence with 43.78 % role in fruit damage on number basis, followed by minimum temperature (39.78 %), while minimum temperature played a major role (33.09 %) in the variation of fruit damage on weight basis, followed by afternoon RH (29.44 %) and average temperature (26.40 %‘). The results of the present investigation was supported by the findings of Pramanik (2010), who reported that during 2003-04 major contribution was made by maximum temperature (94.55%) on the variation in shoot damage, while, during 2004-05 minimum temperature had maximum influence on shoot damage (82.75 %) followed by maximum temperature (12.47 %) and relative humidity (3.10 %). However, on the variation in fruit damage, minimum temperature produced highest contribution (66.59 %) during the year 2003-04 and in the subsequent year maximum temperature and sunshine hours had greater influence with 51.01 and 35.86 % contribution, respectively.

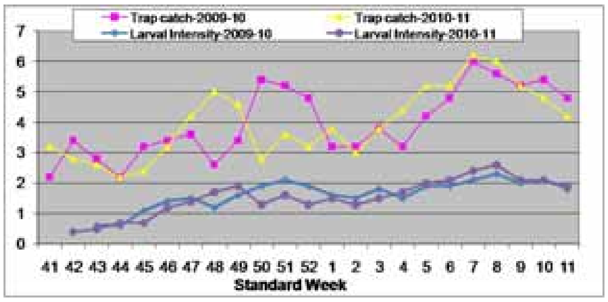


**Fig. 1. Seasonal population dynamics of BSFB during winter 2009-10 and 2010-11**

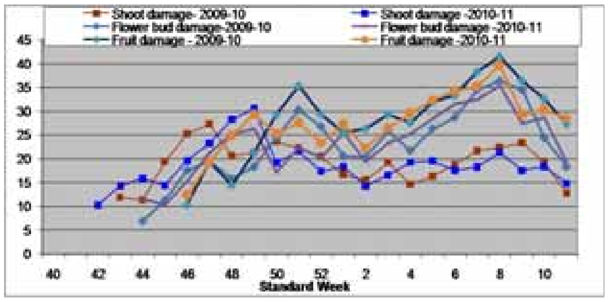


**Fig. 2. Seasonal variation in infestation level of BSFB during winter 2009-10 and 2010-11**

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# YIELD MAXIMIZATION OF *RABI*-SUMMER GROUNDNUT THROUGH NUTRIENT MANAGEMENT PRACTICES IN THE *KONKAN* REGION OF MAHARASHTRA

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ABSTRACTS

The field experiment was conducted at Agricultural Research Station, Shirgaon, Tal. Dist. Ratnagiri (MS) on the lateritic soil during *rabi* summer season of 2009-10, 2010-11 and 2011-12 to study yield maximization of groundnut (*Arachis hypogaea* L.) through nutrient management practices. The factors considered were application of Farm Yard Manure (FYM) and Recommended Dose of Fertilizers (RDF) in various combinations. Application of 100% RDF as basal + 50% RDF as top dressing at 30 DAS along with FYM @ 7.5 t $ha^{-1}$ recorded significantly higher pod yield, kernel yield and haulm yield (2844 Kg, 2020 Kg and 2990 Kg $ha^{-1}$, respectively) over 100% RDF as basal (2125, 1634 and 2101 Kg $ha^{-1}$, respectively). Significantly higher number of pods and dry pod weight was in case of application of 75 % RDF as basal and 75 % RDF at 30 DAS with FYM @ 7.5 t $ha^{-1}$ and was at par with application of 100% RDF as basal + 50% RDF as top dressing at 30 DAS along with FYM @ 7.5 t $ha^{-1}$. Soil pH was increased from 5.2 to 5.4. Organic carbon was significantly higher (0.85 %) in application of 100% RDF as basal + 50% RDF as top dressing at 30 DAS along with FYM @ 7.5 t $ha^{-1}$ as compared to initial content (0.66 %). Higher net returns and B:C ratio was observed at application of 100 % RDF as basal + 50% RDF as top dressing (Rs. 23018/- and 1.45, respectively).

**Key words**: Groundnut, nutrients, FYM, Top dressing, Pod yield, Net returns

The groundnut (*Arachis hypogaea* L.) is considered to be the one of the most important food legume and oilseed crops in the world. It is grown in over 100 countries of the world and plays a crucial role in the world economy. The impact of groundnut crop in the oilseed scenario of India and its reflection on the country's economy has been highly significant. Groundnut is dominating other oilseeds of the country by sharing 35 to 45 % of the total area under oilseeds and 45 to 55 % of the total oilseeds production.

Presently, the average productivity of groundnut, in India is around 1300 Kg $ha^{-1}$ which is very low as compared to USA and China mainly because, the crop is mostly grown as *rainfed* and in dry lands, under low fertility and low input management, often subject to the vagaries of the weather conditions. However, in recent years, combination of improved genotypes and nutrient management practices has increased the productivity. *Konkan* region has the potential for non-traditional area, where groundnut can be grown in both the rainy and the post rainy seasons with the productivity range of 2.0 to 3.0 t $ha^{-1}$. Intensification of food grain production resulted in excessive removal of plant

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nutrients from the soil and hence corrective measures are necessary for sustainability. Groundnut needs large amount of N, P, K and Ca and various micronutrients. Amount of N fixed by root nodules, N content of the soil and cost: benefit ratio of N application determines rate of nitrogen application (Kathmale and Kambale, 2010).

Groundnut is an unpredictable legume, since its response to nutrient application is always not optimistic. Considering the availability of the major nutrients in the soil and quantum of losses due to leaching and/or fixation of the individual elements expected, a proper method and the time of nutrient application are needs of the hour. These facts call for a concerted study on the possibility of more effective utilization of nutrients in divided dosages like basal and top dressing. The review is aimed to have better understanding on optimizing the nutrient requirement and uptake in increasing the pod yield of groundnut and benefits of interactions between the organic and inorganic fertilizers.

The optimization of the mineral nutrition is the key to optimize the production of groundnut, as it has very high nutrient requirement and the recently released high yielding groundnut varieties remove still more nutrients from the soil. On contrary groundnut farmers, most part of the semi-arid region use very less nutrient fertilizer and sometime only one or two nutrients resulting in severe mineral nutrient deficiencies due to inadequate and imbalance use of nutrients is one of the major factors responsible for low yield in groundnut. India is the world's largest producer of groundnut where nutritional disorders cause yield reduction from 30-70 per cent depending upon the soil types. Laxminarayana and Patiram (2005) reported that the integrated use of inorganic and organic manures in combination with farmyard manure gave the highest pod and haulm yields. Thus it is high time to look into the mineral nutrition aspects of groundnut for achieving high yield and advocate the suitable package of practices for optimization of yield.

Thus the present study was undertaken to assess the production maximization of groundnut through nutrient management practices.

## Materials and Methods

The field experiments was conducted at Research Farm of Agricultural Research Station, Dr. B.S. Konkan Krishi Vidyapeeth, Shirgaon, Dist. Ratnagiri (MS) during the *rabi* summer season started during 2009-10 and completed in the year 2011-12. The experiment was laid out in randomised block design with ten treatments replicated four times in *rabi* summer seasons. The treatments were ($T_1$)- Recommended Dose of Fertilizers (RDF) (100 %) as basal (25:50:00 Kg NPK $ha^{-1}$), ($T_2$)- $T_1$ + Farm Yard Manure (FYM) @ 7.5 t $ha^{-1}$, ($T_3$)- RDF (75 % ) as basal + RDF ( 25 % ) as top dressing at 30 DAS, ($T_4$)- $T_3$ + FYM @ 7.5 t $ha^{-1}$, ($T_5$)- RDF (150 %) as basal, ($T_6$)- $T_5$ + FYM @ 7.5 t $ha^{-1}$, ($T_7$)- RDF (100 % ) as basal + RDF ( 50 % ) as top dressing at 30 DAS, ($T_8$)- $T_7$ + FYM @ 7.5 t $ha^{-1}$, ($T_9$)- RDF (75 % ) as basal + RDF ( 75 % ) as top dressing at 30 DAS and ($T_{10}$)- $T_9$ + FYM @ 7.5 t $ha^{-1}$.

The experimental soil was lateritic with slightly acidic in reaction (5.20 pH), 0.050 $dSm^{-1}$ electrical conductivity, medium in organic carbon (0.66 %), medium in available nitrogen (282.2 kg ha$^{-1}$), low in available phosphorus (9.80 kg ha$^{-1}$) and medium in available potassium (239.8 kg ha$^{1}$). The nutrients were applied in through the chemical fertilizers like urea and single super phosphate. The FYM and RDF was mixed in soil at the time of field preparation as per treatments. Groundnut variety Trombay Konkan Groundnut-Bold (TKG-Bold) was sown at 30 X 15 cm spacing using a seed rate of 125Kg ha$^{-1}$.

The groundnut crop was harvested at maturity. The pod and haulm yield of groundnut was recorded separately for each net plot and yield per hectare was calculated. The data was analysed following Panse and Sukhatme (1985). Plot wise surface (0-20 cm) soil samples were collected after the harvest of groundnut crop. These samples were analysed for pH (1:2.5), organic carbon by Walkley and Black method (Walkley and Black, 1934), available N by alkaline potassium permagnate method (Subbiah and Asija, 1956), available P by Olsen's method (Olsen et al. 1954) and available K by ammonium acetate method of flame photometer (Jackson, 1967).

**Table 1. Plant height, no. of branches, total number of pods, dry pod weight, shelling percentage, sound mature kernels and hundred kernel weight of groundnut as influenced by different treatments (Pooled data of three years)**

| Treatment | | Plant height at harvest (cm) | No. of branches plant$^{-1}$ | Total No. of pods plant$^{-1}$ | Dry pod weight g plant$^{-1}$ | Shelling % | Sound mature Kernels % | 100 Kernel weight g |
|---|---|---|---|---|---|---|---|---|
| $T_1$ | RDF (100 %) as basal (25:50:00 NPK Kg ha$^{-1}$) | 40.7 | 5.8 | 12.5 | 18.5 | 75.7 | 85.0 | 58.0 |
| $T_2$ | $T_1$ + FYM @ 7.5 t ha$^{-1}$ | 41.1 | 5.8 | 13.5 | 19.3 | 74.7 | 86.2 | 59.5 |
| $T_3$ | RDF (75 % ) as basal + RDF (25%) as top dressing at 30 DAS | 43.1 | 5.8 | 13.2 | 19.2 | 73.6 | 86.0 | 56.1 |
| $T_4$ | $T_3$ + FYM @ 7.5 t ha$^{-1}$ | 40.9 | 5.7 | 14.1 | 20.4 | 74.5 | 88.4 | 60.2 |
| $T_5$ | RDF (150 %) as basal | 40.4 | 6.0 | 13.8 | 21.0 | 72.7 | 86.1 | 58.6 |
| $T_6$ | $T_5$ + FYM @ 7.5 t ha$^{-1}$ | 40.9 | 5.8 | 15.0 | 22.0 | 74.0 | 84.7 | 59.5 |
| $T_7$ | RDF (100%) as basal + RDF (50%) as top dressing at 30 DAS | 44.2 | 5.7 | 14.2 | 20.7 | 72.4 | 84.9 | 56.3 |
| $T_8$ | $T_7$ + FYM @ 7.5 t ha$^{-1}$ | 43.2 | 6.3 | 16.0 | 23.7 | 70.9 | 85.9 | 58.6 |
| $T_9$ | RDF (75 %) as basal + RDF (75%) as top dressing at 30 DAS | 41.2 | 5.8 | 14.9 | 21.6 | 75.2 | 86.6 | 58.2 |
| $T_{10}$ | $T_9$ + FYM @ 7.5 t ha$^{-1}$ | 42.6 | 5.7 | 16.1 | 24.0 | 74.3 | 85.0 | 58.7 |
| | Mean | 41.8 | 5.8 | 14.3 | 21.0 | 73.8 | 85.9 | 58.4 |
| | S.E. ± | 2.03 | 0.40 | 0.78 | 1.19 | 0.52 | 1.1 | 1.3 |
| | CD at 5% | NS | NS | 2.19 | 3.35 | 1.45 | 3.0 | 3.6 |
| | CV (%) | 9.3 | 12.8 | 10.3 | 10.7 | 1.3 | 2.4 | 4.1 |

## Results and Discussion

### Yield attributes

In the pooled data plant height and number of branches per plant were found to be non significant. However total number of pods and dry pod weight were affected significantly due to different treatments under study. Significantly higher number of pods and dry pod weight was in case of application of 75 % RDF as basal and 75 % RDF at 30 DAS with FYM @ 7.5 t $ha^{-1}$ and was at par with application of 100% RDF as basal + 50% RDF as top dressing at 30 DAS along with FYM @ 7.5 t $ha^{-1}$.

### Yield

The pooled data of three years (*Rabi* summer season 2009-10, 2010-11 and 2011-12) presented in the Table 2 and in mean of three years data indicated that application of 100% RDF as basal + 50% RDF as top dressing at 30 DAS along with FYM @ 7.5 t $ha^{-1}$ recorded significantly higher pod yield, kernel yield and haulm yield (2844, 2020 and 2990 Kg $ha^{-1}$, respectively) over 100% RDF as basal. Ravikumar and Raghavalu (1995) reported that split application of nitrogen equally at sowing and at 35 DAS increased the pod yield.

**Table 2. Dry pod yield, kernel yield, haulm yield and harvest index of groundnut as influenced by different treatments (Pooled data of three years)**

| Treatments | | Dry pod yield Kg $ha^{-1}$ | Kernel yield Kg $ha^{-1}$ | Dry Haulm Yield Kg $ha^{-1}$ | Harvest Index |
|---|---|---|---|---|---|
| $T_1$ | RDF (100 %) as basal (25:50:00 NPK Kg $ha^{-1}$) | 2125 | 1634 | 2101 | 0.44 |
| $T_2$ | $T_1$ + FYM @ 7.5 t $ha^{-1}$ | 2306 | 1727 | 2252 | 0.44 |
| $T_3$ | RDF (75 % ) as basal + RDF ( 25 % ) as top dressing at 30 DAS | 2305 | 1705 | 2396 | 0.41 |
| $T_4$ | $T_3$ + FYM @ 7.5 t $ha^{-1}$ | 2404 | 1794 | 2560 | 0.41 |
| $T_5$ | RDF (150 %) as basal | 2342 | 1700 | 2475 | 0.41 |
| $T_6$ | $T_5$ + FYM @ 7.5 t $ha^{-1}$ | 2542 | 1892 | 2560 | 0.43 |
| $T_7$ | RDF (100 % ) as basal + RDF ( 50 % ) as top dressing at 30 DAS | 2634 | 1906 | 2837 | 0.40 |
| $T_8$ | $T_7$ + FYM @ 7.5 t $ha^{-1}$ | 2844 | 2020 | 2990 | 0.41 |
| $T_9$ | RDF (75 % ) as basal + RDF ( 75 % ) as top dressing at 30 DAS | 2349 | 1772 | 2397 | 0.43 |
| $T_{10}$ | $T_9$ + FYM @ 7.5 t $ha^{-1}$ | 2602 | 1908 | 2555 | 0.43 |
| | Mean | 2445 | 1806 | 2512 | 0.42 |
| | S.E. $\pm$ | 92.68 | 70.1 | 166.0 | — |
| | CD at 5% | 260.36 | 197.0 | 466.3 | — |
| | CV (%) | 7.2 | 7.3 | 12.3 | — |

**Table 3. Soil properties and nutrient status at harvest as influenced by different treatments**

| Treatments | | Nutrient contents in soil | | | | |
|---|---|---|---|---|---|---|
| | | pH | Org. C (per cent) | Available N (Kg $ha^{-1}$) | Available $P_2O_5$ (Kg $ha^{-1}$) | Available $K_2O$ (Kg $ha^{-1}$) |
| $T_1$ | RDF (100 %) as basal (25:50:00 NPK Kg $ha^{-1}$) | 5.4 | 0.69 | 285.8 | 9.90 | 266.5 |
| $T_2$ | $T_1$ + FYM @ 7.5 t $ha^{-1}$ | 5.4 | 0.82 | 292.3 | 12.50 | 278.3 |
| $T_3$ | RDF (75 % ) as basal + RDF ( 25 % ) as top dressing at 30 DAS | 5.3 | 0.70 | 288.8 | 11.55 | 275.0 |
| $T_4$ | $T_3$ + FYM @ 7.5 t $ha^{-1}$ | 5.4 | 0.83 | 291.5 | 10.30 | 252.6 |
| $T_5$ | RDF (150 %) as basal | 5.4 | 0.64 | 288.3 | 10.78 | 263.2 |
| $T_6$ | $T_5$ + FYM @ 7.5 t $ha^{-1}$ | 5.3 | 0.79 | 301.3 | 11.38 | 266.3 |
| $T_7$ | RDF (100 % ) as basal + RDF ( 50 % ) as top dressing at 30 DAS | 5.2 | 0.71 | 292.0 | 9.80 | 246.4 |
| $T_8$ | $T_7$ + FYM @ 7.5 t $ha^{-1}$ | 5.3 | 0.85 | 302.5 | 10.60 | 270.2 |
| $T_9$ | RDF (75 % ) as basal + RDF ( 75 % ) as top dressing at 30 DAS | 5.2 | 0.73 | 296.8 | 10.58 | 278.9 |
| $T_{10}$ | $T_9$ + FYM @ 7.5 t $ha^{-1}$ | 5.4 | 0.83 | 296.3 | 10.80 | 267.1 |
| | S.E. ± | 0.04 | 0.03 | 5.10 | 0.79 | 11.78 |
| | CD at 5% | 0.11 | 0.09 | NS | NS | NS |
| | Initial soil status | 5.2 | 0.66 | 282.21 | 9.80 | 239.8 |

## Nutrient uptake

Soil pH and organic carbon significantly affected due to application of different treatments under study. Soil pH was increased from 5.2 to 5.4. Organic carbon was significantly higher (0.85 %) in application of 100% RDF as basal + 50% RDF as top dressing at 30 DAS along with FYM @ 7.5 t $ha^{-1}$ as compared to initial content (0.66 %). However available nitrogen, available $P_2O_5$ and available $K_2O$ were non significant at harvest. Ismail *et al.* (1998) reported significantly increase in organic C, available N and P content of the soil with application of FYM possibly due to the increase in decomposition product of organic matter.

## Economics

Maximum variable cost was observed in treatment $T_{10}$ i.e. application of RDF (75 % ) as basal + RDF ( 75 % ) as top dressing at 30 DAS and + FYM @ 7.5 t $ha^{-1}$ followed by $T_8$ i.e. application of RDF (100 % ) as basal + RDF ( 50 % )

**Table 4. Economics as influenced by different treatments (Pooled data of three years)**

| Treatments | | Gross Returns (Rs $ha^{-1}$) | Cost of Cultivation (Rs. $ha^{-1}$) | Net Returns (Rs. $ha^{-1}$) | B:C Ratio |
|---|---|---|---|---|---|
| $T_1$ | RDF (100 %) as basal (25:50:00 NPK Kg $ha^{-1}$) | 59162 | 49769 | 9394 | 1.19 |
| $T_2$ | $T_1$ + FYM @ 7.5 t $ha^{-1}$ | 64467 | 57549 | 6917 | 1.12 |
| $T_3$ | RDF (75 % ) as basal + RDF ( 25 % ) as top dressing at 30 DAS | 64305 | 50276 | 14029 | 1.28 |
| $T_4$ | $T_3$ + FYM @ 7.5 t $ha^{-1}$ | 67428 | 57813 | 9614 | 1.16 |
| $T_5$ | RDF (150 %) as basal | 65419 | 50304 | 15115 | 1.30 |
| $T_6$ | $T_5$ + FYM @ 7.5 t $ha^{-1}$ | 71186 | 58271 | 12916 | 1.22 |
| $T_7$ | RDF (100 % ) as basal + RDF (50 % ) as top dressing at 30 DAS | 73589 | 50571 | 23018 | 1.45 |
| $T_8$ | $T_7$ + FYM @ 7.5 t $ha^{-1}$ | 79260 | 58535 | 20725 | 1.35 |
| $T_9$ | RDF (75 % ) as basal + RDF ( 75 % ) as top dressing at 30 DAS | 65799 | 50571 | 15229 | 1.30 |
| $T_{10}$ | $T_9$ + FYM @ 7.5 t $ha^{-1}$ | 72803 | 58778 | 14026 | 1.24 |
| | Mean | 68342 | 54244 | 14098 | 1.26 |

**Rates**

| *Rabi* summer season | Groundnut pod (Rs. $Kg^{-1}$) | Haulm (Rs. $Kg^{-1}$) | Labour (Rs. $day^{-1}$) | N (Rs. $Kg^{-1}$) | $P_2O_5$ (Rs. $Kg^{-1}$) | FYM (Rs. $Tonne^{-1}$) | Gr.nut Seed (Rs. $Kg^{-1}$) |
|---|---|---|---|---|---|---|---|
| 2009-10 | 25 | 0.80 | 120 | 10.78 | 21 | 800 | 46.6 |
| 2010-11 | 26 | 1.00 | 120 | 10.78 | 21 | 1000 | 46.6 |
| 2011-12 | 30 | 1.00 | 120 | 12.54 | 21 | 1000 | 50.0 |

as top dressing at 30 DAS + FYM @ 7.5 t $ha^{-1}$. Cultivation cost increased with increased level of FYM and RDF. Higher gross returns was obtained in application of treatment $T_8$ followed by treatment $T_{10}$. The maximum net returns and benefit cost ratio was observed at application of 100 % RDF as basal + 50% RDF as top dressing (Rs. 23018/- and 1.45, respectively).

It was concluded that for obtaining higher productivity and profit from *rabi* summer groundnut in lateritic soils of *Konkan* it is recommended to apply 100% RDF (25 Kg N + 50 Kg $P_2O_5$) at the time of sowing and 50% RDF (12.5 Kg N + 25 Kg $P_2O_5$) as top dressing at one month after sowing.

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# MANAGEMENT OF CROP RESIDUES IN RICE –WHEAT CROPPING SYSTEM ON CROP PRODUCTIVITY AND SOIL PROPERTIES THROUGH CONSERVATION EFFECTIVE TILLAGE IN NORTH WESTERN INDIA

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## Abstract

Rice (Oryza sativa L.) and wheat (Triticum aestivum L.) are now grown in sequence on the same land in the same year over an area about 65 mha in Punjab, Haryana, and Western Uttar Pradesh states, out of this rice is grown on 40 mha and wheat on 25 mha in these states crescent has been the heartland of the Green Revolution (GR). and this system contribute more than 70 % of total cereal production in India to meet the food demand of a rapidly expanding human population.This rice-wheat (RW) system brings together conicting and complementary practices. Much of the system operates at low yield because of inadequate nutrients and inappropriate water management.The challenge to research is to understand crop responses to the required combination of practices so that management systems can be devised for high and sustainable combined yield.The repeated transitions from anaerobic to aerobic to anaerobic growing conditions affect soil structure, nutrient relations,the growth of the component crops,and their associated pests and diseases.Due to these reasons the sustainability of rice-wheat system under great threat.A field experiment was conducted over 03 years in Sardar Vallabhbhai Patel University of Agriculture &Technology,Meerut,U.P.India,to discusses the existing problems and improve resource-use effciency of existing practices and to look for new production strategies that might avoid existing constraints in areas of the R-W region. In particular, soil, water and residue management strategies, such as reduced tillage and use of raised beds, that avoid the deleterious effects of puddling on soil properties, improve water use effciencies,and increase crop productivity, may be appropriate.

**Key Words**: Crop residue, Permanent raised beds, Soil quality, Productivity

## Introduction

The rice–wheat cropping system being the oldest and most prevalent agricultural practices in India, is also practised in many other regions of the world and wetland culture is the predominant soil management system adopted. Rice occupies 153 m ha land throughout the world. In India, out of the 43 m ha area under rice cultivation,puddled rice culture occupies 24 m ha, about 56% of the area (Anonymous, 2005).This involves ploughing the soil when wet,puddling it and keeping the area flooded for the duration of the rice crop.Wetland rice culture thus destroys soil structure and creates a poor physical condition for the following wheat crop.This soil condition can reduce wheat yield (Boparai *et al.*,1992) presumably by limiting root growth and distribution (Oussible *et al.*,1992).For regeneration and maintenance of soil structure within this cropping system,plant residue is very important (Verma and Bhagat, 1992;Naresh et al., 2013),but for various reasons,the amount of residue being returned to the soil is not adequate.Rice grown with conservation tillage can produce yields similar to that under conventional puddling with minimized expenses on field preparations (Sharma and De Datta,1986; Naresh 2013). Besides declining soil fertility, low wheat yields in rice-wheat cropping system are also obtained due to a short turnover period between rice harvest and delayed wheat sowing due to a number of factors, including delayed rice transplanting resulting in delayed rice harvest,high soil moisture content after the rice harvest,delay in removal of rice straw (a large part of it is being burned *in situ*,which besides the loss of precious organic C creates environmental and health problems), etc.

India produces about 500-550 Mt of crop residue annually (MNRE 2009).There is a large variability in generation of crop residues and their use depending on the crops grown, cropping intensity and productivity in different regions of India. Residue generation is highest in Uttar Pradesh (60 Mt) followed by Punjab (51 Mt) and Maharashtra (46 Mt). Among different crops, cereals generate 352 Mt residues followed by fibres (66 Mt), oilseed (29 Mt),pulses (13 Mt) and sugarcane (12 Mt) (Figure 1).The cereal crops (rice, wheat, maize,millets) contribute 70% while rice crop alone contributes 34% of crop residues (Figure 1).Wheat ranks second with 22% of residues whereas fibre crops contribute 13% of residues generated from all crops.Among fibres,cotton generates maximum (53 Mt) with 11% of crop residues. Coconut ranks second among fibre crops with 12 Mt of residue generation.Sugarcane residues comprising tops and leaves generate 12 Mt i.e.,2% of crop residues in India.Generation of cereal residues is also highest in Uttar Pradesh (53 Mt) followed by Punjab (44 Mt) and West Bengal (33 Mt).Maharashtra contributes maximum to the generation of residues of pulses (3 Mt) while residues from fibre crop is dominant in Andhra Pradesh (14 Mt). Gujarat and Rajasthan generate about 6 Mt each of residues from oilseed crops.Total plastic waste which is dumped in India annually 56 lakh tonnes (CPCB 2013) and recycled in the country is estimated to be 9,205 tonnes per day (appreoximately 60% of total plastic waste) and 6,137 tonnes remain uncollected and littered.This waste is a source of continuing pollution as plastic is not bio-degradable and poisons the environment.

**Uses and on-farm burning of crop residues in India**

The uses of crop residues are different in different states of the country. Farmers use residues either themselves or sell it to landless households or intermediaries, who in turn sell the residues to industries. The remaining residues are left unused or burned on-farm.Traditionally crop residues have numerous competing uses such as animal feed, fodder,fuel,roof thatching, packaging and composting. Cereal residues are mainly used as cattle feed.Rice straw and husk is used as domestic fuel or in boilers for parboiling rice in West Bengal.In states like Punjab, Haryana and western Uttar Pradesh, where rice residues are not used as cattle feed,a large amount rice straw is burned on-farm.Sugarcane tops in most parts of the country are either used for feeding of dairy animals or burned on-farm for growing a ratoon crop. Residues of groundnut are burned as fuel in brick kilns and lime kilns. Cotton, chilli, pulses and oilseeds residues are mainly used as fuel for household needs.

Coconut shell, stalks of rapeseed and mustard, pigeon pea and jute and sunflower are used as domestic fuel.

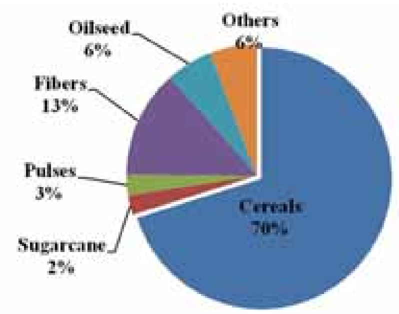


**Fig. 1. Contribution of various crops in India in generating residues (Calculated from MNRE 2009)**

The surplus residues i.e., total residues generated less residues used for various purposes, are typically burned on-farm.Estimated total crop residue surplus in India is 84-141 Mt $yr^{-1}$ where cereals and fibre crops contribute 58% and 23%,respectively (Figure 2).Remaining 19% is from sugarcane, pulses, oilseeds and other crops. Out of 82 Mt surplus residues from the cereal crops, 44 Mt is from rice followed by 24.5 Mt from wheat, which is mostly burned on-farm.In case of fibre crops (33 Mt of surplus residue) approximately 80% is cotton residues are subjected to on-farm burning. sunflower are used as domestic fuel.Pathak et al., (2010) estimated that

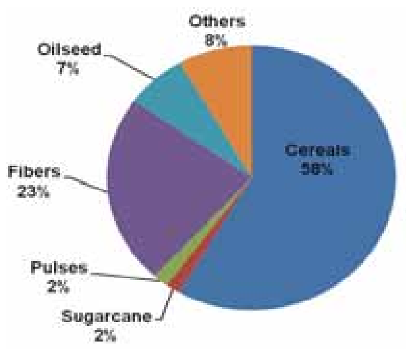


**Fig. 2. Contribution of various crops in generating surplus residues in India (Calculated from MNRE 2009)**

about 93 Mt of crop residues are burned on-farm.

## Adverse consequences of on-farm burning of crop residues

Burning of crop residues leads to 1) release of soot particles and smoke causing human health problems; 2) emission of greenhouse gases (GHGs) such as carbon dioxide, methane and nitrous oxide causing global warming; 3) loss of plant nutrients such as N, P, K and S; 4) adverse impacts on soil properties and 5) wastage of valuable C and energy-rich residues. In addition to loss of entire amount of C, 80% of N, 25% of P, 50% of S and 20% of K present in straw are lost due to burning. If the crop residues are incorporated or retained, the soil will be enriched, particularly with organic carbon and N.Heat from burning residues elevates soil temperature causing death of bacterial and fungal populations. However, the death is temporary as the microbes regenerate after few days.Repeated burning in the field, however, permanently diminishes the microbial population. Burning immediately increases the exchangeable $NH_4^+$-N and bicarbonate extractable P content but there is no build up of nutrients in the profile. Long-term burning reduces total N and C and potentially mineralizable N in the 0-15 cm soil layer.

Burning of agricultural residues, represents a significant source of chemically and radiatively important trace gases and aerosols such as methane ($CH_4$), carbon monoxide (CO), nitrous oxide ($N_2O$), oxides of nitrogen ($NO_X$) and other hydrocarbons to the atmosphere affecting the atmospheric composition. Burning of residues emits a significant amount GHGs. About 70,7 and 0.7% of C present in rice straw is emitted as carbon dioxide,carbon monoxide and methane, respectively, while 2% of N in straw is emitted as nitrous oxide upon burning.It also emits large amount of particulates that are composed of wide variety of organic and inorganic species.One ton of rice straw on burning releases about 3 kg particulate matter, 60 kg CO,1460 kg $CO_2$,199 kg ash and 2 kg $SO_2$ (Gadi 2003;Derpsch and Friedrich 2010 ).Besides other light hydrocarbons, volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs) including polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), SOx and NOx are also emitted. These gases are important for their global impact and may lead to a regional increase in the levels of aerosols, acid deposition, increase in tropospheric ozone and depletion of the stratospheric ozone layer.They may subsequently undergo trans-boundary migration depending upon the wind speed/direction, reactions with oxidants like $OH^-$ leading to physico-chemical transformation and wash out by precipitation. Many pollutants found in large quantities in biomass smoke are known or suspected carcinogens and could be a major cause of concern leading to various air-borne/lung diseases (Fig. 3).

**Fig. 3. Burning of rice residues, a prevalent practice in north western India**

It is a paradox that burning of crop residues and scarcity of fodder coexists in this country and there is significant increase in fodder prices in recent years.Industrial demand for crop residues is also increasing. There are several options such as animal feed, composting, energy generation, biofuel production and recycling in soil to manage the residues in a productive and profitable manner. Conservation agriculture (CA) offers a good promise in using these residues for improving soil health, increasing productivity, reducing pollution and enhancing sustainability and resilience of agriculture (Gupta and Seth 2007).The resource conserving technologies (RCTs) involving no- or minimum-tillage, direct seeding, bed planting with innovations in residue management are possible alternatives to the conventional energy- and input-intensive agriculture.

## Adverse impacts of residues removal for competing uses

There are numerous direct and indirect adverse impacts of residue removal on ecosystem services, including depletion of the SOC pool (Fig. 4). Important among direct impacts of residue removal are low input of biomass C, reduction in nutrient/elemental cycling,decrease in food/energy source and habitat for soil biota along with the attendant decline in soil quality. There are also numerous indirect impacts of residue removal. Notable among these are increase in risks of soil erosion and runoff because of decrease in aggregation and increase in soil's susceptibility to crusting and compaction. The loss of water and nutrients from the ecosystems also decreases crop growth and yields and reduces agronomic productivity. Removal of crop residues have indicted the adverse impacts as outlined in Figure 4.(Blanco-Canqui and Lal, 2007). Mann et al., (2002) argued that more research information is needed to determine potential long-term effects of residue harvest,including (1) erosion and water quality, especially pesticides and nitrates,(2) rates of transformation of different forms of SOC, (3) effects on soil bioata, and (4) SOC dynamics in subsoil.

## MATERIALS AND METHODS

An experiment was conducted on rice-wheat cropping system in three districts (Meerut,Ghaziabad and Saharanpur ) in farmers participatory mode in the juridiction of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (Uttar Pradesh), India, (28°402 073 N to 29°282 113 N, 77°282 143 E to 77° 44 183 E,237m above mean sea level) during 2009-10 to 2011-12.These trials farmer-managed,with a single replicate, repeated over many farmers. Therefore,

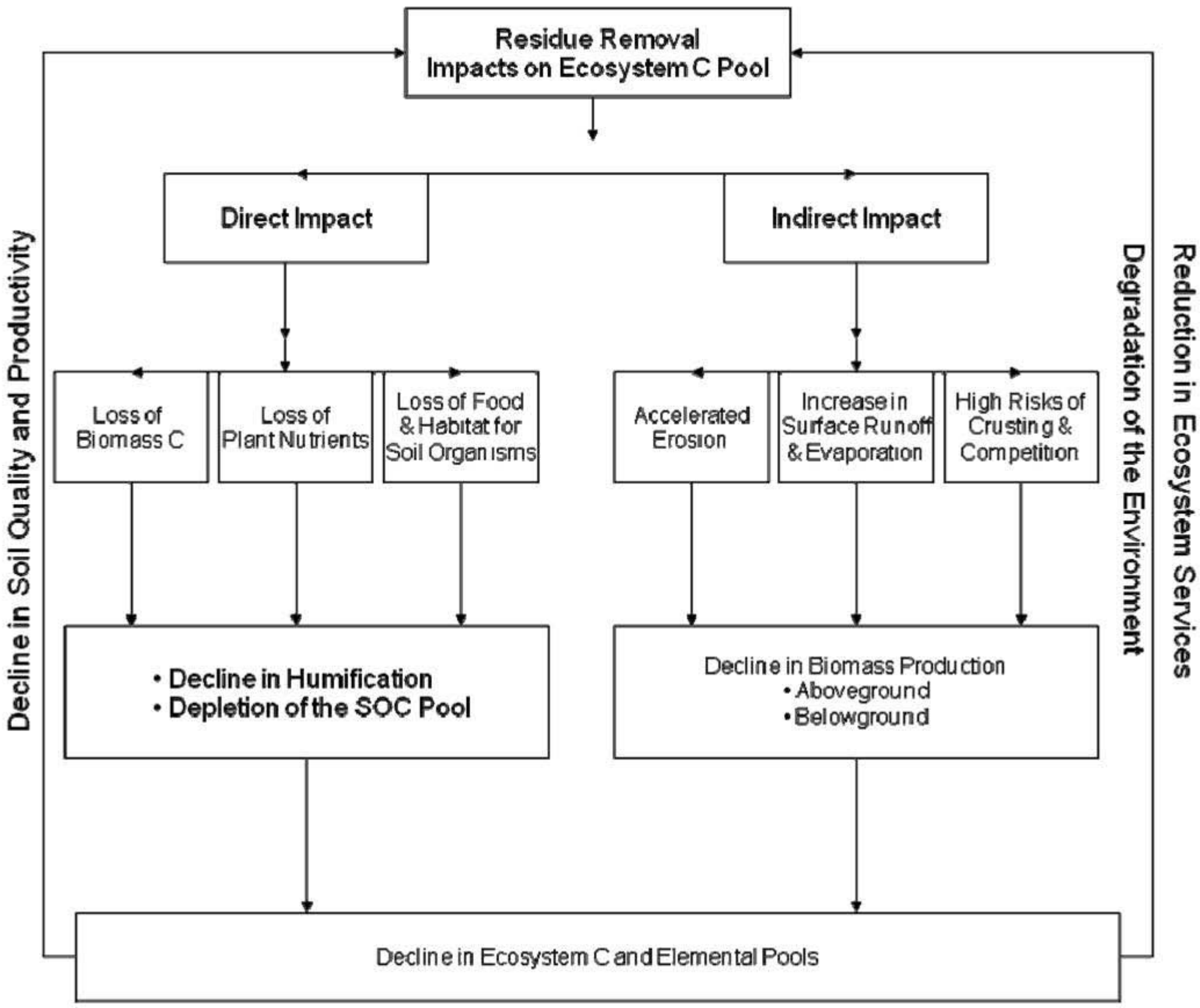


**Fig. 4. Adverse impacts of crop residues removal on depletion of the ecosystem carbon pool, decline in ecosystem services, and degradation of the environment**

**Table 1: Treatments in the replicated experiment in rice-wheat cropping system.**

| Kharif season | | Rabi season | |
|---|---|---|---|
| **Layout** | **Abbrevations** | **Layout** | **Abbrevations** |
| $T_1$-Conventional till puddled transplanted rice with Sesbania co culture | CT-TPR +S | $T_1$-Zero till wheat planted by turbo happy seeder | ZT-HS |
| $T_2$ -Direct seeded rice on permanent wide raised beds | WBed- DSR | $T_2$-Zero till wheat on Permanent wide raised beds + residue burn | WBed-ZTW+ RB |
| $T_3$ -Direct seeded rice on permanent wide raised beds with Sesbania co culture | WBed–DSR+S | $T_3$-Zero till wheat on Permanent wide raised beds+ 50% residue retained | WBedZTW+ 50% RR |
| $T_4$-Transplanted rice on permanent wide raised beds with Sesbania co-culture | WBed -TPR+S | $T_4$-Zero till wheat on Permanent wide raised beds +100% residue retained | WBed-ZTW+ 100% RR |
| $T_5$ -Transplanted rice on permanent wide raised beds | WBed - TPR | $T_5$-Zero till wheat on flat beds + residue burn | FBed -ZTW +R |
| $T_6$ -Zero till unpuddled transplanted rice | ZT-TPR | $T_6$-Zero till wheat on flat beds + 50% residue retained | FBed ZTW+50% RR |
| $T_7$ -Zero till unpuddled transplanted rice with sesbania co culture | ZT-TPR +S | $T_7$-Zero till wheat on flat beds + 100% residue retained | FBed -ZTW +100%RR |
| $T_8$- Conventional till puddled transplanted rice | CT- TPR | $T_8$-Conventional tillage practices broadcast wheat | CT- BCW |

the experimental design was a Randomized Block Design in which the number of treatments varied from farmer to farmer, with the farmer as a replicate/ block.The climate of the area is semiarid,with an average annual rainfall of 665 mm (75–80% of which is received during July to September),minimum temperature of $4^0$C in January, maximum temperature of 41 to $45^0$C in June,and relative humidity of 67 to 83% throughout the year.In general the soils of the experimental sites was silty loam in texture with medium fertility status.The particle size distribution of 0-20 cm soil layer is 68.3 % sand,17.4 % silt and 14.7 % clay.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 bulk density of 1.54 Mg $m^{-3}$, weighted mean diameter of soil aggregates 0.58 mm, infiltration rate 58.3mm $hr^{-1}$, cone index 2.45, total C 8.3 g $kg^{-1}$.

**Experimental design and treatments**

The experiment comprised on rice-wheat cropping system, and was designed as a randomised complete block design with three replicates,commencing with kharif in 2009.The plots consisted of ten layout or crop establishment straw treatments.The sites,treatments and management are briefly summarised here for convenience.

Seeding the sesbania was knock down by spraying with 2,4-D ester @ 400 g a.i $ha^{-1}$. In the transplanted rice sesbania was sown ex-situ on the same day as the dry seeding, and was applied as a green manure mulch (after cutting into 10–12 cm lengths) to the transplanted rice on the same day as it was sprayed in the DSR plots.

*Rice residues in wheat (+R).* Rice residues (partiall anchored, partially loose) amounting to 6 t $ha^{-1}$ were retained in the +R treatments. In the raised beds the rice residues were cut at ground level and removed before sowing, then spread uniformly as mulch after sowing. In the flat plots wheat was direct drilled into the rice residues using a turbo happy seeder/inclined plate metering device multi crop zero till cum bed planter.

## Results and Discussion

**Crop productivity:** Straw retention increased yield rapidly, starting from the second crop cycle.This is an important finding because,if repeated on farmers'fields,farmers will quickly realise the benefits and be more interested in adopting the technology (Table 2),presents the grain yields cropwise and year wise.The highest yield was observed in wide beds with 100%residue retention.Yields tended to be lower in $T_8$ than $T_1$.Yields on raised beds consistently increased as residue retention increased from 0% to 100% but the differences between $T_4$ and $T_5$ were not always significant for the three rice-wheat crop cycles. Permanent beds with residue retention increased yield by 4-17% in rice - wheat as compared to conventional practices.This is an important finding in relation to practical management of such systems by farmers.Since there is high demand for straw for fodder,fuel or building materials in the IGP especially by small- and medium-scale farmers,it is encouraging that retaining only 50% of the straw will provide adequate benefit to the crop while the remainder can be removed for other uses.The crop residues retained as surface mulch (partially

**Table 2. Productivity of rice–wheat systems under various residue management and crop establishment Techniques**

| Crop Establishment | | Grain yield t ha$^{-1}$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2009-10 | | | 2010-11 | | | 2011-12 | | |
| **Rice** | **Wheat** | **Rice** | **Wheat** | **RW System** | **Rice** | **Wheat** | **RW System** | **Rice** | **Wheat** | **RW System** |
| $T_1$-CT-TPR +S | $T_1$-Z T-HS | 5.15 | 4.95 | 10.10 | 4.95 | 5.20 | 10.15 | 5.10 | 5.25 | 10.35 |
| $T_2$ -WBed- DSR | $T_2$ -WBed-ZTW+ RB | 4.05 | 5.15 | 9.20 | 4.10 | 5.05 | 9.15 | 4.35 | 5.10 | 9.45 |
| $T_3$ -WBed–DSR+S | $T_3$-WBed-ZTW+ 50%RR | 3.95 | 5.25 | 9.20 | 4.45 | 5.20 | 9.65 | 4.65 | 5.45 | 10.10 |
| $T_4$ WBed -TPR+S | $T_4$ WBed-ZTW+ 100%RR | 4.55 | 5.45 | 10.00 | 5.05 | 5.50 | 10.55 | 5.05 | 5.60 | 10.65 |
| $T_5$ -WBed - TPR | $T_5$ -FBed -ZTW +RB | 4.75 | 5.15 | 9.90 | 4.60 | 5.10 | 9.70 | 4.45 | 5.05 | 9.50 |
| $T_6$ -ZT-TPR | $T_6$ -FBed -ZTW+50%RR | 4.30 | 5.25 | 9.55 | 4.55 | 5.20 | 9.75 | 4.65 | 5.15 | 9.80 |
| $T_7$ -ZT-TPR +S | $T_7$ -FBed -ZTW +100%RR | 4.25 | 5.35 | 9.60 | 4.75 | 5.30 | 10.05 | 4.85 | 5.45 | 10.30 |
| $T_8$- CT- TPR | $T_8$- CT- BCW | 5.35 | 4.20 | 9.55 | 5.15 | 4.10 | 9.25 | 4.95 | 4.05 | 9.00 |
| C D at 5 % | | 0.92 | 0.51 | - | 0.85 | 0.46 | - | 0.63 | 0.59 | - |

anchored and partially loose) would have helped in regulating the soil temperature and moisture, but it is assumed that the greater yield response was mainly due to the aberration in weather conditions during the crop growth period.Green and Lafond (1999) reported that surface residues in a no-till system helped to buffer soil temperature and that,during winter,soil temperature (at 5 cm depth) with residue removal and conventional tillage was on average 0.29 °C lower than that with no tillage and surface retained residues. Conversely soil temperature during summer was 0.89 °C higher under conventional tillage than the no-till situation with surface residue retained.

## Improved water use efficiency

WUE,based on the amount of grain produced per m$^3$,increased by 25–30% on raised beds,largely because more water was used by basin planting with flood irrigation.Figures 5 and 6 indicate that the soil water of raised bed planting changes gradually,that is the ratio of gain and loss is balanced.The soil water of basin planting, however, changes more markedly and does not increase as much with increase in soil depth. Traditional basin planting requires better conditions for smoothing/levelling of the field, while raised bed planting has the benefit of better distributing the limited water in the soil and thus creating a more stable soil water environment for the growing root system.The change with time of the soil moisture content in different layers of the soil (Figures 7,8) shows that the two planting methods display similar characteristics in the 0–15 cm layer,where the soil moisture content fluctuates greatly.But in the 15–30 cm layer,the extent of soil moisture changes basin planting is greater than that for

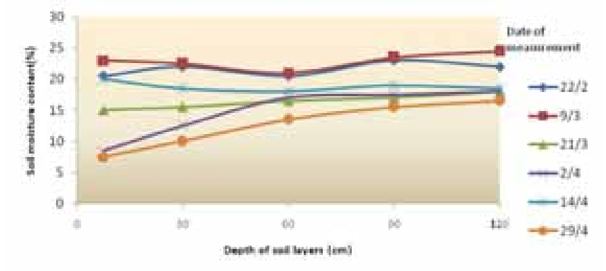


**Fig. 5. Vertical changes of soil moisture content at different stages of raised bed planting**

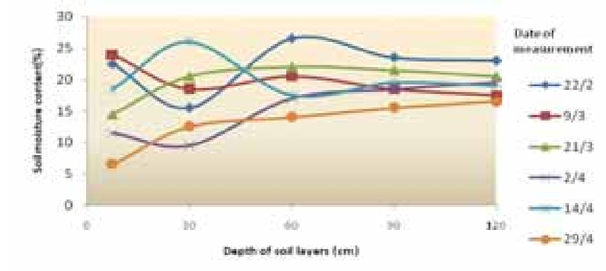


**Fig. 6. Vertical changes of soil moisture content at different stages of flat planting**

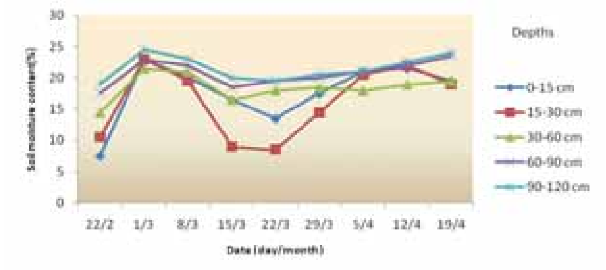


**Fig. 7. Dynamic change of soil moisture content in different layers of soil in raised bed planting**

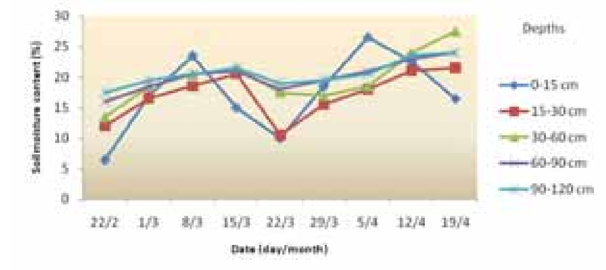


**Fig. 8. Dynamic change of soil moisture content in different layers of soil in flat planting**

raised bed planting. The soil moisture at 15–30 cm at jointing stage for basin planting was only 10% or so,while that of raised bed planting was kept at 14%.We can conclude that an increase in water consumption led to a decrease in soil moisture in the basin planting,and that the range in soil water content of traditional basin planting is greater than that of raised bed planting wheat.

## Planting system and Soil quality

Residue management practices affect soil physical properties such as aggregate formation, bulk density and soil porosity.Soil from permanent raised beds with full residue retention had significantly higher mean weight diameter (MWD) compared to conventional tilled flat beds (Table 3). Permanent raised beds with full residue retention had a significantly longer time compared to the treatment with complete residue removal.The effect of plant residue removal on soil structure in permanent raised beds was very clear as the MWD decreased with decreasing amounts of residues retained.Macro-porosity and aggregation are increased as active organic matter builds up.Soil aggregation refers to the cementing or binding together of several primary soil particles into secondary units.Aggregate breakdown is a good measure for soil erodibility,as breakdown to finer, more transportable particles and microaggregates, increases erosion risk (Le Bissonais 2003).Conventionally tilled flat beds and permanent raised beds without residue cover present as such a high erosion risk.A lower aggregation results in a reduction of the infiltration and storage capacity of the soil by forming a relatively impermeable soil layer by sealing of pores (Le Bissonais 2003, Naresh *et al.*, 2010). This

**Table 3. Effect of crop establishment on bulk density, water stability of aggregates, cone index and MWD etc. soil properties under rice-wheat cropping system after 03 year's of experimentation.**

| Treatment | Bulk density (Mg $m^{-3}$) | Aggregate porosity (%) | Water Stable aggregates >0.25 mm (%) | Cone index (Kg/$cm^2$) | MWD |
|---|---|---|---|---|---|
| $T_1$ | 1.58 | 38.2 | 67.7 | 6.79 | 0.60 |
| $T_2$ | 1.56 | 40.8 | 73.9 | 4.79 | 0.62 |
| $T_3$ | 1.55 | 41.2 | 79.0 | 3.40 | 0.64 |
| $T_4$ | 1.53 | 42.7 | 81.9 | 2.51 | 0.69 |
| $T_5$ | 1.54 | 41.3 | 80.2 | 4.63 | 0.63 |
| $T_6$ | 1.57 | 39.6 | 69.8 | 5.81 | 0.65 |
| $T_7$ | 1.59 | 40.2 | 70.1 | 5.59 | 0.61 |
| $T_8$ | 1.69 | 37.3 | 66.2 | 8.49 | 0.57 |
| Initial | 1.54 | - | - | 2.45 | 0.58 |
| CD at 5% | 0.23 | 1.74 | 5.3 | 0.83 | 0.09 |

corresponded with the higher time to confirm the results found in permanent raised beds with residue retention compared to permanent raised beds with residue removal.

At initial time bulk density of surface layers remained lower under residue retained bed planting than under conventional tillage.This is because top of beds remains loose.Bed planting provides natural opportunity to reduce compaction by confining traffic to the furrow bottoms [Govaerts,et al.,2006].The lower bulk density means more porosity especially in upper surface.With the passage of time the differences between soil physical parameters get narrowed because height of bed gets reduced and become compacted.The cone index was increased significantly under all the tillage and crop establishment techniques but the extent of increase was more under conventional tillage systems.As a result of better physical environment (loose soil) under bed planting,than that of CT system,which was reflected in yield improvement. Permanent raised bed planting practices have been developed to reduce production costs while conserving resources and sustaining the environment and numerous benefits have been observed in comparison with other planting systems. Less is known, however, about how residue management, partial or completely retained, or tillage practices, i.e. permanent raised beds versus conventional tillage in which raised beds are formed each year, affect physical and chemical soil quality.

## Conclusions

Crop residues, usually considered a problem,when managed correctly can improve nutrient cycling, thereby creating a rather favourable environment for plant growth.The recycling of its residues has the great potential to return a considerable amount of plant nutrients to the soil in the rice based crop production systems.The yield stagnation consequent upon the declining soil organic carbon is a major threat to this system.Therefore it is a great challenge to the agriculturists to manage rice residues effectively and efficiently for enhancing sequestration of carbon and maintaining the sustainability of production.Rice residue management is also important as machines are being increasingly used for harvesting of grains,and this mechanical harvesting leaves huge amount of residues in the field.There are several options for management of rice residues:burning, incorporation, surface retention etc.Every management options have its advantages as well as disadvantages.Now it is the location,soil and situation,which will govern the practice to be selected of course,intensive research is required to solve this problem of managing rice residues.Sometimes surface retention may be the best option in many situations. For sowing/ planting of subsequent crops having rice residues, both stubbles and loose straw in the field needs to be managed,for that intensive investigation in different rice growing areas is required. Using crop residues for competing uses (e.g., fuel, fodder, industrial and construction material) has adverse impacts on soil quality and agronomic productivity. Among numerous biophysical and socio-economic and political constraints to adopting CA, removal of crop residues is an important non-tenurial factor. Beneficial impacts of residue retention are especially high to resource-poor and small size land holders of the developing countries who cannot afford the off-farm input of fertilizers, herbicides, etc.

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# SEASONAL INCIDENCE OF GRAM POD BORER, *HELICOVERPA ARMIGERA* (NOCTUIDAE: LEPIDOPTERA) IN CHICK PEA

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## ABSTRACT

The first appearance of the gram pod borer (*Helicoverpa armigera* Hubner) was noticed in the second week of December on the crops sown at optimum time, while in the subsequent week on late sown chickpea crop. The crop received first peak of population of pod borer during first week of January in reproductive phase, while the another peak of intensity was recorded in mid February during reproductive phase of the crop. General equilibrium position (GEP) of gram pod borer was observed to be 2.71, 2.55, 2.02 and 2.45 in timely sown crop on KGD-1168, KWR-108, Avarodhi and Udai cultivars of chickpea, respectively, while it was 3.17, 2.99, 2.18 and 3.08 larvae/m row length in delayed sowing on these varieties. The negative and positive association with the population of gram pod borer was determined with temperature and relative humidity, respectively. Wind velocity and sunshine had no impact on the multiplication of this pest, while evaporation rate had significant negative association (r = -0.867 to – 0.919).

## INTRODUCTION

Chick pea (*Cicer arietinum L.*) is one of the oldest and most widely consumed legumes in the world, particularly in tropical and subtropical areas. India is the largest producer of chickpea followed by Pakistan, Turkey and Iran. India occupies first position in the world in terms of area (66%) and production (70%). It is primarily grown in Madhya Pradesh, Rajasthan, Maharashtra, Uttar Pradesh, Andhra Pradesh and Karnataka, but on small scale in Orissa, Bihar, Gujrat, Tamilnadu and Haryana also (Anonymous 2011-12).

Abiotic and Biotic stresses are the major constraints in enhancing the productivity of chickpea in India. Insect – pests and diseases are biotic bottlenecks in realizing its potential yield. To keep pace with the demand of ever increasing human population of the country, there is an urgent need to increase the production of chickpea. One of the most practical means of increasing chickpea production is to minimize losses caused by the biotic factors, which include insect-pests, diseases and weeds under field conditions. Chickpea faces the attack of more than 60 insect-pets right from germination to maturity (Srivastava *et al*, 2005). Among them, gram pod borer, *Helicoverpa armigera* (Hubner) is considered as key pest causing 29% yield losses in chickpea at national level. The young larvae feed on tender portion of the leaves and shoots by making scratches. Second instar and subsequent grown-up larvae consume whole leaf, leaf buds, flower buds, and flowers. On development of pods, the larvae make hole in the pods and move inside to feed on grains. A single larva is capable of destroying 30-40 pods in its larval period (Chaudhary and Chaudhary, 1975).

## MATERIALS AND METHODS

The experiment was executed in Split Plot Design with factorial combination in sub plot with three replications. The experiment was laid out in 9.0m x 4.5 m plot size with block border of 1.5m and 1m plot border. Replication wise mean intensity of the larvae was calculated by averaging the population noticed in randomly selected three rows. Larval intensity of gram pod borer was recorded till the availability of the pest in the field.

After completing the replication wise observations recorded at weekly intervals on the intensity of gram pod borer, general equilibrium position (GEP) of this pest was generated for each treatment by calculating the arithmetic mean of the observations recorded for studying the effect of various treatments. Weekly mean intensity of the pest was also computed for normal sown, late sown crop and irrespective of sowing date to observe the impact of weather parameters prevailing during the crop season.

Simple correlation coefficient (r) values were determined between the intensity of gram pod borer recorded during vegetative phase and reproductive phase and full season on all four varieties sown at 40 cm row spacing with the prevailing weather parameters during the crop season. Data on GEP of pest intensity, pod damage and seed yield were analyzed statistically for their critical differences using Split Plot Design with factorial combination in sub plot.

## RESULTS AND DISCUSSION

Seasonal intensity of gram pod borer was noticed on four varieties *i.e.* KGD-1168, KWR-108, Avarodhi and Udai sown as two different dates *viz.* Nov.3, Nov. 18, 2011 and the observations on gram pod borer intensity were recorded at weekly interval replication wise and their simple mean is presented in Table-1 and Graph-1.

First appearance of gram pod borer was recorded in 49$^{th}$ SW on December 9, 2011 with its initial intensity of 0.27, 0.18, 0.12 and 0.15 larvae /m row on chickpea varieties KGD-1168, KGR-108, Avarodhi and Udai sown Nov. 03, 2011, respectively. There was no initial infestation of this pest on late sown (Nov. 18, 2011) varieties during 49$^{th}$ standard weeks, but it appeared in subsequent weeks with its mild intensity (0.12– 0.24 larvae / m row) on different varieties. The intensity of gram pod borer increased in ensuring weeks and noticed above the economic threshold level of one larva/m row length in the end of December (52$^{th}$ SW). At this stage, there was 1.38, 1.20, 1.15 and 1.21 larvae/m row observed on KGD-1168, KWR-108, Avarodhi and Udai Varieties sown at normal time (Nov. 03, 2011), respectively.

During vegetative phase, maximum population of gram pod borer was noticed 1.73, 1.61, 1.27 and 1.50 larvae/m row length on respective varieties in the first week of January, which could not show variation in pest intensity recorded on these varieties sown on second date of sowing. After this week, the intensity of this pest was observed in a declining trend for next two weeks in 3$^{rd}$ SW during January. In this week the intensity of gram pod borer was noticed to be 0.73, 0.60, 0.36 and 0.49 larvae/m row on the respective varieties sown at normal time (Nov. 03, 2011), which was below economic threshold level of this pest.

**Table 1. Seasonal intensity of gram pod borer on different varieties of chickpea (larvae/m row)**

| Sowing Date | Variety | Intensity of larvae (no./m row) on different dates | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 9/12 | 16/12 | 23/12 | 30/12 | 06/01 | 13/01 | 20/01 | 27/01 | 03/02 | 10/02 | 17/02 | 24/02 | 02/03 | 09/03 | 16/03 | 23/03 | GEP |
| Nov. 03, 11 | KGD 1168 | 0.27 | 0.34 | 0.71 | 1.38 | 1.73 | 1.38 | 0.73 | 2.72 | 5.21 | 6.40 | 8.31 | 6.08 | 5.73 | 1.90 | 0.60 | 0.00 | 2.71 |
| | KWR 108 | 0.18 | 0.24 | 0.61 | 1.20 | 1.61 | 1.33 | 0.60 | 2.68 | 4.85 | 6.30 | 9.12 | 5.29 | 4.75 | 1.60 | 0.50 | 0.00 | 2.55 |
| | Avarodhi | 0.12 | 0.17 | 0.58 | 1.15 | 1.27 | 0.93 | 0.36 | 1.94 | 4.35 | 5.40 | 6.15 | 5.30 | 3.85 | 0.60 | 0.21 | 0.00 | 2.02 |
| | Udai | 0.15 | 0.20 | 0.63 | 1.21 | 1.50 | 1.26 | 0.49 | 3.00 | 4.44 | 6.00 | 8.85 | 5.15 | 4.80 | 1.33 | 0.27 | 0.00 | 2.45 |
| Nov. 18, 11 | KGD 1168 | 0.00 | 0.24 | 0.71 | 1.38 | 1.73 | 1.54 | 1.17 | 3.68 | 7.00 | 6.80 | 9.26 | 7.61 | 5.80 | 2.47 | 0.82 | 0.65 | 3.17 |
| | KWR 108 | 0.00 | 0.21 | 0.61 | 1.20 | 1.61 | 1.49 | 1.09 | 3.40 | 6.45 | 7.05 | 10.07 | 6.50 | 5.40 | 1.86 | 0.58 | 0.41 | 2.99 |
| | Avarodhi | 0.00 | 0.12 | 0.58 | 1.15 | 1.27 | 0.99 | 0.68 | 2.33 | 5.00 | 5.75 | 5.39 | 5.31 | 4.47 | 1.35 | 0.37 | 0.16 | 2.18 |
| | Udai | 0.00 | 0.15 | 0.63 | 1.21 | 1.50 | 1.35 | 0.91 | 3.70 | 6.20 | 7.77 | 10.94 | 6.79 | 5.67 | 1.80 | 0.52 | 0.19 | 3.08 |

However, the intensity of this pest being 1.17, 1.09, 0.68 and 0.91 larvae/m row were noticed on KGD-1168, KWR-108, Avarodhi and Udai varieties sown under late condition. In the end of January, abrupt rise in pest intensity was recorded on the tested varieties, which was 2.72, 2.68, 1.94 and 3.0 larvae/m. row in first sowing date and 3.68, 3.40, 2.33 and 3.70 larvae/m row on second date of sown varieties, respectively. This trend of increasing in pest intensity was continued till mid February *i.e.* 17$^{th}$ SW (Feb. 2, 2012).

In the middle of February maximum intensity of gram pod borer was observed to be 8.31, 9.12, 6.15 and 8.85 larvae/m row in first date of sowing and 9.26, 9.07, 5.39 and 10.94 larvae/m row in second sowing on chickpea varieties KGD-1168, KWR- 108, Avarodhi and Udai, respectively. At this stage the crop was in flowering and pod forming stage. In the middle of March, the pest intensity remained below one larvae/m row being 0.6, 0.5, 0.21 and 0.27 in first date of sowing and 0.82, 0.58, 0.37 and 0.52 larvae/m row in second date of sowing on chickpea varieties KGD-1168, KWR-108, Avarodhi and Udai, respectively. However, there was no intensity of this pest recorded on the varieties sown at optimum time, while below 0.5 larvae/m row on these varieties sown late (Nov. 18, 2011). General equilibrium position (GEP) of gram pod borer for KGD-1168, KWR-108, Avarodhi and Udai varieties was calculated to be 2.71, 2.55, 2.02 and 2.45 larvae/m row length for first date sowing, while it was 3.17, 2.99, 2.18 and 3.08 larvae/m row length in second date of sowing. It can be observed that the pest appeared during second week of November on normal sown crop and in mid November on late sown crop with its intensity of <1 larvae/m row.

The first peak in the intensity of this pest was observed during first week of January irrespective of sowing time, which declined there after till 3rd week of January (Jan. 20, 2012). The pest increased continuously from the end of January to mid of February showing the second peak of intensity in the reproductive phase of crop. These results on the seasonal intensity of gram pod borer on different varieties in similarity with those of Ravi and Verma (1997), who studied the seasonal incidence of *H. armigera* in relation to date of sowing in chickpea and reported that the incidence of *H. armigera* started in the first week of January and reached at its peak in March irrespective of date of sowing. Singh *et al.* (2005) studied that seasonal occurrence of larval population of (*H. armigera* Hubner) on chickpea in northwest Rajasthan. They reported that the larval population increased gradually until the first week of December then declined until the end of January. The population started to increase again from mid February until the second week of April and then declined abruptly. The first peak of larval population was recorded on the first week of December whereas the second peak was registered in the second week of April.

Views of Singh and Yadav (2006) also support these findings, who reported that larval activity of *H. armigera* continued throughout the crop season with two peaks in both year, i.e. the first from 45 to 49 standard weeks and the second from 5 to 13 standard weeks. The highest mean larval populations of 6.3 and 6.4 larvae/m$^2$ were observed in 45 and 12 standard week, respectively.

The findings of Chatar *et al.* (2010) regarding the appearance of gram pod borer in chickpea from 2nd week of December to 3rd week of January and decline in population gradually towards the maturity of the crop, confirms the present studies.

**Relationship between intensity of gram pod borer and weather parameters**

It is evident from the data presented in Table-2 that temperature (maximum, minimum and average) showed negative relationship with intensity of gram pod borer noticed on all the tested varieties of chickpea sown on different dates. Maximum temperature play more important role for the multiplication of this pest during vegetative phase of the crop, as it showed non significant negative correlation (r) values of -0.652, -0.676, -0.629 and -0.678 with the borer intensity noticed on KGD-1168, KWR-108, Avarodhi and Udai varieties sown at optimum time (Nov.3 2011), respectively. Similarly, the value of simple correlation coefficient were calculated to be -0.723, -0.729, -0.674 and -0.719 for the respective varieties sown under late condition (Nov. 18, 2011). It is evident from data on seasonal intensity of gram pod borer on different varieties sown on different dates that first peak of intensity was recorded in first SW of January during vegetative phase, while the second peak was obtained in February (7th standard week) average temperature of 11.10 to 14.60$^0$C (maximum 18-22.6$^0$C and minimum 4.1–11.1$^0$C) during vegetative phase of crop, while average temperature between 13.40-16.30$^0$C (maximum 19.30-23.8$^0$C and Min. 8.3-11.5$^0$C) during reproductive phase of the crop were found suitable for the best multiplication for this pest.

Relative humidity showed non-significant positive correlation with intensity of gram pod borer in chick pea exhibiting simple correlation coefficient

**Table 2. Simple correlation coefficient (r) between intensity of gram pod borer in different varieties of chickpea and weather parameters during 2011-12**

| Sowing date | Variety | Crop stage | Temperature ($^0C$) Max. | Temperature ($^0C$) Min. | Temperature ($^0C$) Av. | Relative humidity (%) Max. | Relative humidity (%) Min. | Relative humidity (%) Av. | Wind velocity (km/hr) | Evapo-ration Rate (mm/day) | Sun shine (hrs/ day) | Rainall (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nov 3, 2011 | KGD-1168 (V1) | Vegetative | -0.652 | -0.058 | -0.458 | 0.094 | 0.706 | 0.701 | -0.287 | -0.868* | -0.711 | 0.610 |
| | | Reprodutive | -0.308 | 0.405 | -0.357 | 0.489 | 0.241 | 0.388 | -0.289 | -0.525 | 0.007 | 0.316 |
| | | Over all | 0.018 | -0.899 | -0.029 | -0.009 | -0.061 | -0.042 | 0.141 | -0.315 | 0.250 | 0.286 |
| | KWR-108 (V2) | Vegetative | -0.676 | -0.036 | -0.461 | 0.060 | 0.746 | 0.733 | 0.333 | -0.868* | -0.748 | 0.601 |
| | | Reprodutive | -0.337 | -0.409 | -0.375 | 0.483 | 0.248 | 0.381 | -0.341 | -0.545 | -0.093 | 0.322 |
| | | Over all | -0.013 | -0.101 | -0.053 | 0.03 | -0.049 | -0.029 | 0.092 | -0.339 | 0.181 | 0.292 |
| | Avarodhi (V3) | Vegetative | -0.629 | -0.169 | -0.506 | 0.171 | 0.611 | 0.623 | 0.123 | -0.889* | -0.632 | 0.564 |
| | | Reprodutive | -0.321 | -0.401 | -0.362 | 0.531 | 0.293 | 0.431 | -0.288 | -0.549 | -0.023 | 0.371 |
| | | Over all | -0.012 | -0.115 | -0.059 | 0.053 | -0.031 | 0.006 | 0.101 | -0.353 | 0.217 | 0.331 |
| | Udai (V4) | Vegetative | -0.678 | -0.098 | -0.498 | 0.067 | 0.712 | 0.702 | 0.261 | -0.890* | -0.722 | 0.571 |
| | | Reprodutive | -0.34 | -0.417 | -0.381 | 0.490 | 0.264 | 0.395 | -0.331 | -0.552 | -0.061 | 0.309 |
| | | Over all | -0.018 | -0.114 | -0.063 | 0.014 | 0.043 | -0.020 | 0.093 | -0.348 | 0.193 | 0.281 |
| Nov. 18, 2011 | KGD-1168 (V1) | Vegetative | -0.273 | -0.145 | -0.554 | 0.036 | 0.714 | 0.699 | 0.293 | -0.916* | -0.725 | 0.541 |
| | | Reprodutive | -0.301 | -0.432 | -0.370 | 0.536 | 0.27 | 0.421 | -0.335 | -0.547 | 0.009 | 0.253 |
| | | Over all | 0.052 | -0.078 | -0.004 | -0.039 | -0.086 | -0.072 | 0.163 | -0.301 | 0.286 | 0.227 |
| | KWR-108 (V2) | Vegetative | -0.729 | -0.103 | -0.534 | -0.003 | 0741 | 0.725 | 0.354 | -0.902* | -0.754 | 0.547 |
| | | Reprodutive | -0.356 | -0.444 | -0.402 | 0.525 | 0.285 | 0.424 | -0.367 | -0.572 | -0.094 | 0.296 |
| | | Over all | 0.005 | -0.100 | -0.042 | -0.016 | -0.061 | -0.046 | 0.117 | -0.333 | 0.213 | 0.261 |
| | Avarodhi (V3) | Vegetative | -0.674 | -0.210 | -0.551 | 0.138 | 0.625 | 0.331 | 0.137 | 0.919** | -0.649 | 0.532 |
| | | Reprodutive | -0.345 | -0.452 | -0.399 | 0.549 | 0.317 | 0.453 | -0.292 | -0.554 | 0.023 | 0.405 |
| | | Over all | 0.009 | -0.116 | -0.047 | 0.005 | -0.051 | -0.021 | 0.158 | -0.328 | 0.276 | 0.344 |
| | Udai (V4) | Vegetative | -0.719 | -0.149 | -0.554 | 0.033 | 0.716 | 0.699 | 0.276 | 0.917* | -0.728 | 0.530 |
| | | Reprodutive | -0.356 | -0.431 | -0.396 | 0.516 | 0.279 | 0.416 | -0.356 | 0.570 | -0.096 | 0.324 |
| | | Over all | 0.005 | -0.101 | -0.043 | -0.011 | -0.070 | -0.049 | 0.112 | -0.332 | 0.213 | 0.279 |

N.B. * & ** Significant at 5% and 1% level of significance

(r) values of 0.701, 0.733, 0.623 and 0.702 during vegetative phase in normal sown crop and 0.699, 0.725, 0.331 and 0.699 in late sowing of KGD-1168, KWR-108, Avarodhi and Udai varieties of chickpea, respectively,. The impact of average relative humidity was found to reduce, as the correlation values ranged between 0.381 to 0.431 in timely planted crop and 0.416 to 0.453 in late sown chickpea varieties. However, impact of relative humidity on the multiplication of pod borer was not very much prominent during this cropping season. Sunshine hours and rainfall did not play major role on the multiplication of this pest.

Average temperature between 12.60 – 14.80 $^{0}$C (max. 18.0 to 22.6$^{0}$C and min. 7.2 to11.1$^{0}$C) and relative humidity 69.0 to 90 % (max. 87-90 and minimum 51-82%) were found suitable for the multiplication of this pest during the cropping season. Wind velocity, sun shine and rainfall were the non significant weather parameter on gram pod borer in chickpea. Regarding the impact of weather parameters for the multiplication of this pest, the results are in accordance with Vaishampayan and Veda (1980), who reported minimum temperature between 10-14$^{0}$C as most favorable for the development of gram pod borer in chickpea. Singh *et al.* (2005) and Singh and Yadav (2006) reported positive relationship of temperature with the intensity of gram pod borer in chickpea, which did not match with the present findings. However, the work of Chatar *et al.* (2010) regarding negative association of temperature and positive relationship of relative humidity with the larval population of gram pod borer provides full support to the present investigations. Impact of wind velocity, sunshine and rain fall on the multiplication of this pest in chickpea is in conformity with those of Reddy *et al.* (2009)

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# EFFECT OF SOWING DATE, VARIETIES AND ROW SPACING ON THE INTENSITY OF GRAM POD BORER, *HELICOVERPA ARMIGERA* (NOCTUIDAE: LEPIDOPTERA) IN CHICK PEA

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## ABSTRACT

An experiment effect of sowing date, varieties and row spacing on the intensity of gram pod borer, *Helicoverpa armigera* (Noctuidae: Lepidoptera) in chick pea. Chickpea variety KWR-108 sown at 40 cm row spacing was found suitable for normal sowing condition (November 03, 2011) exhibiting moderate larval population of 2.5 larvae/m row length with 6.30% pod damage, which provided significantly maximum seed yield of 1877.78 kg/ha. Under late sown condition chickpea cultivar Udai produced significantly highest seed yield being 1416.67 kg/ha with a larval population of 3.10 larvae/m row length and 3.85% pod damage.

## INTRODUCTION

India is the largest producer of chickpea (*Cicer arietinum* L.) followed by Pakistan, Turkey and Iran. India occupies first position in the world in terms of area (66%) and production (70%). It is primarily grown in Madhya Pradesh, Rajasthan, Maharashtra, Uttar Pradesh, Andhra Pradesh and Karnataka (Anonymous 2011-12).

Abiotic and Biotic stresses are the major constraints in enhancing the productivity of chickpea in India. Insect – pests and diseases are biotic bottlenecks in realizing its potential yield. To keep pace with the demand of ever increasing human population of the country, there is an urgent need to increase the production of chickpea. One of the most practical means of increasing chickpea production is to minimize losses caused by the biotic factors, which include insect-pests, diseases and weeds under field conditions. Chickpea faces the attack of more than 60 insect-pets right from germination to maturity (Srivastava *et al*, 2005). Among them, gram pod borer, *Helicoverpa armigera* (Hubner) is considered as key pest causing 29% yield losses in chickpea at national level. This pest is highly polyphagous and has been reported to feed on more than 181 plant species (Manjunath *et al.*, 1989). The young larvae feed on tender portion of the leaves and shoots by making scratches. Second instar and subsequent grown-up larvae consume whole leaf, leaf buds, flower buds, and flowers. On development of pods, the larvae make hole in the pods and move inside to feed on grains. A single larva is capable of destroying 30-40 pods in its larval period (Chaudhary and Chaudhary, 1975).

In recent years, gram pod borer has caused a serious threat to Indian agriculture in general and chickpea in particular due to the development of resistance towards commonly used insecticides like synthetic pyrethroids and other related problems pertaining to the ecosystem.

## Materials and Methods

The experiment was executed in Split Plot Design with factorial combination in sub plot with three replications. The experiment was laid out in 9.0m x 4.5 m plot size with block border of 1.5m and 1m plot border. Replication wise mean intensity of the larvae was calculated by averaging the population noticed in randomly selected three rows. Larval intensity of gram pod borer was recorded till the availability of the pest in the field.

After completing the replication wise observations recorded at weekly intervals on the intensity of gram pod borer, general equilibrium position (GEP) of this pest was generated for each treatment by calculating the arithmetic mean of the observations recorded for studying the effect of various treatments. Weekly mean intensity of the pest was also computed for normal sown, late sown crop and irrespective of sowing date to observe the impact of weather parameters prevailing during the crop season.

Observations on damaged pods due to *H. armigera* (%) were recorded replication wise on 10 plants to find out the impact of agronomic alternations on the incidence of this pest. Arithmetic means of all the weekly observation ns on the intensity of gram pod borer were calculated treatment wise, which were further averaged for computing the general equilibrium position (GEP) of the pest for the treatments. Simple correlation coefficient (r) values were determined between the intensity of gram pod borer recorded during vegetative phase and reproductive phase and full season on all four varieties sown at 40 cm row spacing with the prevailing weather parameters during the crop season. Data on GEP of pest intensity, pod damage and seed yield were analyzed statistically for their critical differences using Split Plot Design with factorial combination in sub plot.

## Results and Discussion

Weekly observations on the intensity of gram pod borer in chickpea varieties KGD-1168, KWR-108, Avarodhi and Udai sown at Nov. 3, 2011 and Nov. 18, 2011 with three row spacing 30 cm, 40 cm and 50 cm were recorded replication wise. Pod damage (%) and seed yield were also recorded for obtaining the role of sowing date, varieties and row spacing for the management of gram pod borer. Thus, data obtained on general equilibrium position (GEP) of gram pod borer, pod damage (%) and seed yield were computed for their critical differences using appropriate statistical tools. The results obtained on different parameters are being presented head-wise under here:

### Intensity of pod borer, *H. armigera*

It is evident from the results portrayed in Table 1 that the crop sown at normal time on November 3, 2011 had significantly lower intensity of 2.43 larvae/m row length than the late sown crop on November 18, 2011 showing 2.82 larvae/m row length. Among the varieties, significantly lowest population of this pest being 2.10 larvae / m row length was recorded on Avarodhi followed by KWR-108, Udai (2.75 larvae/m row length) and KGD 1168 (2.92 larvae/m row length). The role of row spacing on the multiplication of gram pod borer in chickpea is well clear that the crop sown

**Table 1. Effect of sowing dates, varieties and row spacing on overall mean intensity of gram pod borer during 2011-12**

| Variety and row spacing | Intensity of gram pod borer (No./m row) | | |
|---|---|---|---|
| | Nov. 03 2011 ($D_1$) | Nov. 18 2011 ($D_2$) | Mean |
| KGD-1168 at 30cm ($V_1S_1$) | 3.53 (1.88) | 4.04 (2.01) | 3.80 (1.95) |
| KGD-1168 at 40cm ($V_1S_2$) | 2.72 (1.65) | 3.17 (1.78) | 2.92 (1.71) |
| KGD-1168 at 50cm ($V_1S_3$) | 2.07 (1.44) | 2.25 (1.50) | 2.20 (1.47) |
| Mean | 2.76 (1.66) | 3.10 (1.76) | 2.92 (1.71) |
| KWR-108 at 30 cm ($V_2S_1$) | 3.30 (1.81) | 3.76 (1.94) | 3.53 (1.88) |
| KWR-108 at 40 cm ($V_2S_2$) | 2.56 (1.60) | 2.99 (1.73) | 2.75 (1.66) |
| KWR-108 at 50 cm ($V_2S_3$) | 1.93 (1.39) | 2.22 (1.49) | 2.07 (1.44) |
| Mean | 2.56 (1.60) | 2.96 (1.72) | 2.75 (1.66) |
| Avarodhi at 30 cm ($V_3S_1$) | 2.50 (1.58) | 2.92 (1.71) | 2.75 (1.65) |
| Avarodhi at 40 cm ($V_3S_2$) | 2.01 (1.42 | 2.19 (1.48) | 2.10 (1.45) |
| Avarodhi at 50 cm ($V_3S_3$) | 1.46 (1.21) | 1.66 (1.29) | 1.56 (1.25) |
| Mean | 1.96 (1.40) | 2.22 (1.49) | 2.10 (1.45) |
| Udai at 30 cm ($V_4S_1$) | 3.13 (1.77) | 3.61 (1.90) | 3.38 (1.84) |
| Udai at 40 cm ($V_4S_2$) | 2.46 (1.57) | 3.09 (1.76) | 2.75 (1.66) |
| Udai at 50 cm ($V_4S_3$) | 1.93 (1.39) | 2.46 (1.57) | 2.19 (1.48) |
| Mean | 2.50 (1.58) | 3.02 (1.74) | 2.75 (1.66) |
| Overall Mean | 2.43 (1.56) | 2.82 (1.68) | 2.62 (1.62) |
| Factor combinations | SE (m) | $CD_{5\%}$ | $CD_{1\%}$ |
| Sowing date | 0.00 | 0.02 | 0.04 |
| Variety | 0.00 | 0.01 | 0.01 |
| Spacing | 0.00 | 0.01 | 0.01 |
| Variety X Spacing Variety over sowing date | 0.010.00 | 0.020.01 | 0.020.02 |
| Spacing over sowing date | 0.00 | 0.01 | 0.02 |
| Variety X spacing vs. sowing date | 0.01 | 0.02 | 0.03 |

NB: Figures in parentheses are " x transformation

at 30 cm row spacing received significantly highest population of 3.35 larvae/m row length, which was reduced in 40 cm and 50 cm row spacing showing 2.62 and 1.99 larvae/m row length, respectively. This trend for the intensity of this pest revealed that crop sown at wider spacing *i.e.* 50 cm had lower pest intensity than the crop planted densely at 30 cm and 40 cm spacing. Chickpea variety Avarodhi sown at 40 cm row spacing at optimum sowing time (November 3, 2011) showed significantly lowest intensity of 1.46 larvae / m row length followed by 1.66 larvae/m row length on the same variety sown at same row spacing under late sown condition.

It can be inferred from the above cited result that the chickpea crop sown at optimum time (November 3, 2011) received significantly lower intensity of gram pod borer being 2.43 larvae / m row length than the crop sown in late condition harbouring 2.82 larvae/m row length on the basis of general equilibrium position (GEP) of gram pod borer in chickpea. Among the tested four varieties of chickpea, Avarodhi was least preferred by this pest showing 2.10 larvae / m row length followed by KGD 1168, Udai 2.76 larvae/m row length and KWR-108 2.92 larvae/m row length. Densely populated chickpea crop planted at 30 cm row spacing was severely infested by gram pod borer in comparison to the wider spacing 40 cm and 50 cm.

**Pod Damage**

Statistical analysis of the data obtained on pod damage (%) in different varieties of chickpea sown two dates with three row spacing revealed that sowing date, variety and spacing proved their significant impact on the pod infestation, while their interactions were found non-significant (Table-2). It is evident from the results that early sown crop (November 3, 2011) had significantly lowest pod infestation of 5.89 % than 6.66% pod damage recorded on late sown crop (November 18, 2011). Significantly lowest pod damage of 4.09% was recorded in variety Avarodhi followed 5.52% in Udai, 7.10% in KWR-108 and 8.71% KGD-1168. The role of row spacing in chickpea on the pod damage due to gram pod borer showed that significantly lowest pod damage of 5.23% was obtained in chickpea sown 50 cm apart followed by 5.92% and 7.72% pod damage recorded in the crop sown at 40 and 30 cm distance rows, respectively.

However, chickpea variety Avarodhi sown at optimum time with 50 cm row spacing exhibited statistically lowest pod damage of 2.49%, which was followed by 3.30% pod infestation recorded on the same variety at same row spacing sown under delayed condition although, chickpea variety Udai sown at 40 cm spacing in late situation (November 18, 2011) exhibited good performance showing pod infestation of 3.85 %, which was numerically at per with 3.30% pod damage recorded on Avarodhi sown at 50 cm spacing under late sown situation.

The data depicted in Table-3 revealed that significantly highest seed yield of chickpea being 1610.88kg/ha was harvested from the crop sown at optimum sowing time (November 3, 2011) followed by 1216.44 kg/ha seed production obtained from the crop sown under late condition (November 18, 2011). The role of chickpea varieties on the seed yield is well clear that KWR-108 produced significantly highest seed yield being 1526.85 kg/ha followed by 1391.02, 1368.52 and 1368.06 kg/ha seed yield achieved from KGD-1168, Avarodhi and Udai varieties of chickpea irrespective of sowing time and row spacing, respectively.

However, chickpea variety KWR-108 superseded significantly over other tested varieties producing maximum seed yield of 1785.19 kg/ha, when the crop was sown at normal sowing time irrespective of row spacing. Under late sown

**Table 2. Effect of sowing dates, varieties and row spacing on pod damage (%) in chickpea during 2011-12**

| Variety and row spacing | pod damage (%) | | |
|---|---|---|---|
| | Nov. 03 2011 ($D_1$) | Nov. 18 2011 ($D_2$) | Mean |
| KGD-1168 at 30cm ($V_1S_1$) | 9.29 (17.75) | 10.97 (19.34) | 10.11 (18.54) |
| KGD-1168 at 40cm ($V_1S_2$) | 8.32 (16.77) | 9.36 (17.82) | 8.83 (17.30) |
| KGD-1168 at 50cm ($V_1S_3$) | 6.40 (14.65) | 8.26 (16.71) | 7.30 (15.68) |
| Mean | 7.96 (16.39) | 9.50 (17.96) | 8.71 (17.17) |
| KWR-108 at 30 cm ($V_2S_1$) | 8.12 (16.56) | 8.47 (16.92) | 8.30 (16.74) |
| KWR-108 at 40 cm ($V_2S_2$) | 6.30 (14.54) | 7.36 (15.75) | 6.82 (15.14) |
| KWR-108 at 50 cm ($V_2S_3$) | 6.07 (14.26) | 6.50 (14.77) | 6.30 (14.51) |
| Mean | 6.80 (15.12) | 7.42 (15.81) | 7.10 (15.46) |
| Avarodhi at 30 cm ($V_3S_1$) | 5.40 (13.44) | 6.29 (14.53) | 5.84 (13.99) |
| Avarodhi at 40 cm ($V_3S_2$) | 3.30 (10.47) | 4.36 (12.06) | 4.09 (11.26) |
| Avarodhi at 50 cm ($V_3S_3$) | 2.49 (9.09) | 3.30 (10.46) | 2.88 (9.78) |
| Mean | 3.64 (11.00) | 4.57 (12.35) | 4.09 (11.68) |
| Udai at 30 cm ($V_4S_1$) | 6.16 (14.37) | 7.73 (16.15) | 6.92 (15.26) |
| Udai at 40 cm ($V_4S_2$) | 5.76 (13.89) | 3.85 (11.31) | 4.76 (12.60) |
| Udai at 50 cm ($V_4S_3$) | 4.36 (12.06) | 5.65 (13.75) | 4.99 (12.91) |
| Mean | 5.40 (13.44) | 5.64 (13.74) | 5.52 (13.59) |
| Overall Mean | 5.84 (13.99) | 6.66 (14.96) | 6.68 (14.48) |
| Factor combinations | SE (m) | $CD_{5\%}$ | $CD_{1\%}$ |
| Sowing date | 0.14 | 0.87 | 0.04 |
| Variety | 0.30 | 0.86 | 0.01 |
| Spacing | 0.26 | 0.75 | 0.01 |
| Variety X Spacing | 0.52 | NS | NS |
| Variety over sowing date | 0.43 | NS | NS |
| Spacing over sowing date | 0.37 | NS | NS |
| Variety X spacing vs. sowing date | 0.74 | NS | NS |

NB: Figures in parentheses are angular transformed values.

condition, the average seed yield was found to be 1216.44 kg/ha in comparison to 1610.88 kg/ha in normal sown chickpea. Chickpea variety Udai under late sown condition emerged as a best option providing significantly highest seed production of 1347.22 kg/ha. The role of row spacing on seed production of chick pea exhibited that significantly maximum seed production 1479.93 kg/

**Table 3. Effect of sowing dates, varieties and row spacing on seed yield in chickpea during 2011-12**

| Variety and row spacing | Seed yield (kg/ha) | | |
|---|---|---|---|
| | Nov. 03 2011 ($D_1$) | Nov. 18 2011 ($D_2$) | Mean |
| KGD-1168 at 30cm ($V_1S_1$) | 1625.00 | 1225.00 | 1425.00 |
| KGD-1168 at 40cm ($V_1S_2$) | 1666.67 | 1275.00 | 1470.83 |
| KGD-1168 at 50cm ($V_1S_3$) | 1458.33 | 1097.22 | 1277.78 |
| Mean | 1583.33 | 1199.07 | 1391.20 |
| KWR-108 at 30 cm ($V_2S_1$) | 1833.30 | 1291.67 | 1562.50 |
| KWR-108 at 40 cm ($V_2S_2$) | 18.77.78 | 1305.56 | 1591.67 |
| KWR-108 at 50 cm ($V_2S_3$) | 1644.44 | 1208.33 | 1426.39 |
| Mean | 1785.19 | 1268.52 | 1526.85 |
| Avarodhi at 30 cm ($V_3S_1$) | 1700.00 | 1083.33 | 1391.67 |
| Avarodhi at 40 cm ($V_3S_2$) | 1766.67 | 1111.11 | 1438.89 |
| Avarodhi at 50 cm ($V_3S_3$) | 1591.67 | 958.33 | 1275.00 |
| Mean | 1686.11 | 1050.93 | 1368.52 |
| Udai at 30 cm ($V_4S_1$) | 1416.67 | 1375.00 | 1395.83 |
| Udai at 40 cm ($V_4S_2$) | 1500.00 | 1416.67 | 1458.33 |
| Udai at 50 cm ($V_4S_3$) | 1250.00 | 1250.00 | 1250.00 |
| Mean | 1388.89 | 1347.22 | 1368.06 |
| Overall Mean | 1610.88 | 1216.44 | 1413.66 |
| Factor combinations | SE (m) | $CD_{5\%}$ | $CD_{1\%}$ |
| Sowing date | 21.18 | 128.91 | 297.34 |
| Variety | 42.66 | 121.60 | 162.44 |
| Spacing | 36.95 | 105.31 | 140.68 |
| Variety X Spacing | 73.89 | NS | NS |
| Variety over sowing date | 60.33 | 171.97 | 229.72 |
| Spacing over sowing date | 52.25 | NS | NS |
| Variety X spacing vs. sowing date | 104.50 | NS | NS |

NB: Figures in parentheses are angular transformed values.

ha was achieved from the crop sown at 40 cm apart followed by 1443.78 kg/ha in 30 cm row spacing and 1307.29 kg/ha in 50 cm row spacing. The interaction effect of these parameters revealed that superior seed production of 1877.78 kg/ha obtained from chickpea variety KWR-108 sown at 40 cm row spacing under normal sowing time, but chickpea variety Udai performed better over other tested varieties producing highest seed production 1416.7 kg/ha in late sown condition of the crop.

It can be summarized from the above cited results on the effect of agronomic alterations on the population of gram pod borer, pod damage and seed yield of chickpea that chick pea crop sown at normal time (November 3, 2011) received significantly lowest intensity of gram pod borer (2.43 larvae/m row length) and 5.84% pod damage with highest seed production of 1610.88 kg/ha. Significantly highest larval intensity of 3.35/m row length with maximum pod damage being 7.72% were noticed on chickpea sown at 30 cm spacing, which were observed in decreasing order with enhancement in row spacing being 2.62 larvae /m row length with 5.92% pod damage and 1.99 larvae /m row with 5.23% pod infestation in 40 cm and 50 cm apart sown chickpea, respectively. However, significantly maximum yield being 1489.93 kg/ha was obtained from the chickpea crop sowing at 40 cm row spacing, which was on par with 1443.75 kg/ha seed production obtained from 30 cm apart sown chickpea against the statistically lowest seed yield of 1307.29 kg/ha from widest row spacing of 50 cm. On the basis of general equilibrium position (GEP) of gram pod borer, the rank of preference for the tested variety was Avarodhi < KWR-108, Udai < KGD-1168. As far as the seed production is concerned, chickpea variety KWR 108 was found superior under normal sowing situation (785.19 kg/ha), while Udai performed better (1347.22 kg/ha) in delayed sowing situation. This may be due to the yield potential of different varieties of chickpea released for different agro-ecological condition. The present results regarding the status of chickpea varieties against gram pod borer infestation received full support of Singh and Yadav (2006), who reported KGD-1168 and KWR-108 as preferred varieties by gram pod borer showing 23.66 larvae/5 plant with 15.7% pod damage and 21.65 larvae/5 plant with 14.8% pod damage, respectively. Regarding the less preference of Avarodhi variety by this pest are in accordance with Deshmukh *et al.* (2010), who noticed BG 375, HC-1, SAKI-9516, Vijay and Avarodhi as less susceptible varieties of chickpea.

Regarding the role of sowing date on the infestation of gram pod borer in chickpea and its yield, views of different workers are being discussed here in the support of present results. Garg (1990) reported least pod damage of gram pod borer in chickpea sown in October in comparison to late sown crop. Gupta *et al.* (1992) found minimum pod infestation due to *H. armigera* in October sown crop in comparison to late sowing of chickpea upto end of December. They also mentioned increase pod damage pod borer with reduction of seed yield in delayed planting of chickpea. Views of Garg and Verma (1995) also corroborate these results, who noticed lower pod damage with higher seed yield in October sown chickpea than November planted crop. Patnaik (2004) suggested that sowing of chickpea in October was profitable with lesser pod damage and grater seed yield than November sown crop having high pod damage quatum with lower seed production. Chickpea varieties sown at narrow spacing faced higher larval intensity of gram pod borer in comparison to wider spacing (40 cm and 50 cm). These findings can be argued with those of Begum *et al.* (1992) and Patnaik (2004), who reported that closer spacing (30 cm resulted in a higher mean number of eggs and larvae per plant than that of wider spacing.

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# EFFECT OF CROP ESTABLISHMENT TECHNIQUES AND WEED MANAGEMENT PRACTICES ON THE PRODUCTIVITY AND PROFITABILITY OF HYBRID RICE (*ORYZA SATIVA*) - WHEAT (*TRITICUM AESTIVUM*) CROPPING SYSTEM

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## ABSTRACT

A field experiment was conducted at Modipuram, Meerut during the *kharif* and *rabi* season of 2007-08 and 2008-09 to study the effect of crop establishment techniques and weed management practices on the productivity and economics of hybrid rice (*Oryza sativa* L.) - wheat (*Triticum aestivum* L. emend Fiori Paol) cropping system. In this investigation four rice establishment techniques *viz;* puddled transplanting, unpuddled transplanting, puddled drum seeding and direct sowing (line sowing) and six weed management practices *viz*., weedy, weed free, pendimethalin PE @ 1.0 kg a.i./ha, pendimethalin PE @ 1.0 kg a.i./ha + hand weeding at 30 DAS, pendimethalin PE @ 1.0 kg a.i./ha + almix PoE @ 4 g a.i./ha and pendimethalin PE @ 1.0 kg a.i./ha + fenoxaprop-p-ethyl PoE @ 70 g a.i./ha were tested in split plot design with three replications. The study revealed that puddled transplanted rice, being at par with puddled drum seeding recorded significantly highest yield of rice in terms of biological yield (146.3 and 149.2 q/ha) and grain yield (59.9 and 61.4 q/ha). However, in subsequent wheat significantly highest grain yield (47.5 and 50.5 q/ha during 2007-08 and 2008-09, respectively) was recorded after direct seeded rice. The highest net returns and B:C ratio of rice-wheat cropping system were recorded under direct seeding of rice. Pendimethalin @ 1.0 kg a.i./ha + hand weeding followed by pendimethalin @ 1.0 kg a.i./ha + almix @ 4 g a.i./ha recorded significantly highest grain yield (59.8 and 62.5 q/ha), straw yield (83.4 and 85.6 q/ha) and harvest index of rice, which was significantly higher than weedy check and pendimethalin @ 1.0 kg a.i./ha alone. However, in subsequent wheat, significantly highest grain yield (47.3 and 49.9 q/ha during each year, respectively) was recorded under pendimethalin @ 1.0 kg a.i./ha + almix @ 4 g a.i./ha over weedy check. The gross returns, net returns and B:C ratio of rice-wheat cropping system were recorded highest with pendimethalin @ 1.0 kg a.i./ha + almix @ 4 g a.i./ha during both the years.

**Key words:** Crop establishment techniques, Economics, Productivity, Rice-wheat cropping sequence, Weed management practices

## INTRODUCTION

Sustainability of rice-wheat cropping system, vital in providing food security and livelihood to hundreds of millions of people around the globe, is under question due to various environmental, economic and management problems (Fujsaka *et al*., 1994). Hybrid rice is one of the viable and proven technologies available at present to enhance the rice productivity and production in the India. Since, rice is mostly taken as manually transplanted crop under puddled condition the yield is high and water losses through deep seepage and percolation are reduced compare with unpuddled condition, but it has its own

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limitation and ill effect on soil health. This technique is cumbersome, labour intensive and requires continuous pounding of water creating a compacted layer (plough pan) which restrict the percolation of water and creates temporary water logging resulting poor root penetration and growth of succeeding crops (Tomar *et al.*, 2006). Direct seeding of rice in rows, under dry condition; offer a useful option to reduce the adverse effect of puddling. Besides, this also aids in quick establishment and early harvest of rice thereby, early sowing of wheat (Singh *et al.*, 2007).

However, the direct seeded rice culture is subjected to greater weed competition than transplanted rice. Yield reduction due to weeds have been reported to the extent of 25 % in transplanted rice, 32 % in puddled broadcasted rice and 52 % in direct sown rice (Manna, 1991). Hence to avoid yield losses, weed control in direct seeded rice becomes an immensely important practice. Traditionally weed control is done by hand weeding but now a days weeding becomes rather difficult due to costly and scarce labour. Application of herbicides with hand weeding may be a good option to control the weeds. Hence, the present investigation was undertaken to study the effect of sequential application of pre and post-emergence herbicides on yield and economics of rice and wheat under different rice establishment techniques.

## Materials and Methods

A field experiment was conducted during rainy and winter season of 2007-08 and 2008-09 on sandy loamy soil at Crop Research Center of Sardar Vallabhbhai Patel University of Agriculture and Technology, Modiouram, Meerut. ($29^0$ 05' 19" N latitudes, $77^0$ 41' 50" E longitudes and 237 metres above mean sea level). The rainfall during cropping seasons from July to April was 429.5 mm and 480.5 mm during 2007-08 and 2008-09, respectively. The soil at site was sandy loam with organic carbon 0.47 and 0.42, available N 224.1 and 225.6 kg/ha, available P 13.5 and 13.7 kg/ha and available K 176.5 and 177.3 kg/ha, during 2007 and 2008, respectively. The experiment was carried out in split plot design with three replications. The treatments include four rice establishment techniques *viz;* puddled transplanting, unpuddled transplanting, puddled drum seeding and direct sowing (line sowing) and six weed management practices *viz.*, weedy, weed free, pendimethalin PE @ 1.0 kg a.i./ha, pendimethalin PE @ 1.0 kg a.i./ha + hand weeding at 30 DAS, pendimethalin PE @ 1.0 kg a.i./ha + almix PoE @ 4 g a.i./ha and pendimethalin PE @ 1.0 kg a.i./ha + fenoxaprop-p-ethyl PoE @ 70 g a.i./ha to rice. The succeeding wheat was raised on the residual effect of previous crop with recommended package of practices.

Hybrid rice ‘PRH-10’ was sown on 6 and 10 June and; transplanted on 1 and 3 July during 2007 and 2008, respectively. After harvesting of rice, wheat (UP-2338) was sown on 20 and 24 November, 2007 and 2008 and harvested on 5 and 8 April during 2008 and 2009, respectively. Half dose of N was applied at the time of sowing of rice and wheat and the remaining amount of N was top dressed at first and second irrigation. All the treatments were applied to rice as per the standard methods and data on yield attributes and yield were recorded. The economics of rice, wheat and rice-wheat cropping system was recorded based on the prevailing market price of inputs and outputs. Soil samples up to the depth of 30 cm were collected at the end of cropping cycle and analyzed for organic carbon, available NPK content, bulk density, infiltration rate and water holding capacity by following standard laboratory procedures.

## RESULTS AND DISCUSSION

### Effect on rice

The perusal of the results (Table 1) reveals that the rice transplanted in puddled condition gave significantly more yield than other methods. Puddled transplanted rice, being at par with puddled drum seeding recorded significantly highest biological yield (146.3 and 149.2 q/ha), grain yield (59.9 and 61.4 q/ha) and straw yield (86.3 and 87.9 q/ha) of rice during 2007 and 2008, respectively, while the significantly lowest yields were recorded with direct seeding of rice. The grain yield of puddled transplanted rice was 4.9, 10.5 and 8.7%, respectively more over puddled drum seeding, unpuddled transplanting and direct seeding during 2007 and 1.15, 7.91 and 6.04% more during 2008. It

**Table 1. Biological, grain and straw yield (q/ha) and harvest index of rice as influenced by crop establishment techniques and weed management practices**

| Treatment | Biological yield | | Grain yield | | Straw yield | | Harvest index | |
|---|---|---|---|---|---|---|---|---|
| | 2007 | 2008 | 2007 | 2008 | 2007 | 2008 | 2007 | 2008 |
| Crop establishment techniques | | | | | | | | |
| Puddled transplanting (PT) | 146.3 | 149.2 | 59.9 | 61.4 | 86.3 | 87.9 | 0.41 | 0.41 |
| Puddled drum seeding (PDS) | 138.2 | 144.6 | 57.1 | 60.7 | 81.1 | 83.5 | 0.41 | 0.42 |
| Unpuddled transplanting (UPT) | 132.9 | 137.1 | 54.2 | 56.9 | 78.4 | 80.2 | 0.41 | 0.41 |
| Direct seeding (DS) | 128.5 | 134.2 | 55.1 | 57.9 | 73.8 | 76.2 | 0.42 | 0.43 |
| SEm± | 2.28 | 2.29 | 0.49 | 0.47 | 1.92 | 1.93 | 0.005 | 0.005 |
| CD (P=0.05) | 7.9 | 7.9 | 1.7 | 1.6 | 6.6 | 6.7 | NS | NS |
| Weed management practices | | | | | | | | |
| Weedy ($W_0$) | 114.9 | 119.3 | 41.7 | 44.3 | 73.3 | 74.9 | 0.36 | 0.37 |
| Weed-free ($W_1$) | 151.1 | 156.2 | 66.2 | 69.2 | 84.9 | 87.0 | 0.44 | 0.44 |
| Pendimethalin (PE) ($W_2$) | 133.3 | 137.6 | 56.3 | 58.8 | 77.0 | 78.9 | 0.42 | 0.43 |
| Pendimethalin + HW at 30 DAS/DAT ($W_3$) | 142.1 | 146.8 | 59.8 | 62.5 | 83.4 | 85.6 | 0.42 | 0.43 |
| Pendimethalin +Almix at 25 DAS/DAT ($W_4$) | 141.3 | 146.1 | 58.9 | 61.3 | 81.6 | 83.6 | 0.41 | 0.42 |
| Pendimethalin + Fenoxaprop at 25 DAS/DAT ($W_5$) | 136.1 | 141.7 | 56.8 | 59.9 | 79.2 | 81.8 | 0.42 | 0.42 |
| SEm± | 1.97 | 1.91 | 0.49 | 0.51 | 1.91 | 1.87 | 0.01 | 0.01 |
| CD (P=0.05) | 5.6 | 5.5 | 1.5 | 1.5 | 5.5 | 5.3 | 0.02 | 0.03 |

could be due to favourable soil physico-chemical properties and low initial weed competition for crop growth under puddle conditions. Puddling as a means of improving the productivity of rice through land submergence and weed control is well documented (Singh *et al.*, 1995). Puddled transplanted method also had positive effect on size of grain, ear weight and numerically positive effect on grains/ panicle, panicle length, productive tillers which cumulatively resulted in significant increasing in the grain yield. The extent of increase in straw yield of rice due to rice sowing in puddled condition over direct sowing and unpuddled transplanting was attributed to better tiller production and height of plant. The results are in conformity with the findings of Singh *et al.* (2006). The significantly maximum values of harvest index (0.42 and 0.43) were noticed in direct seeding, while the minimum harvest index (0.41 and 0.41) was recorded with puddled transplanted rice during 2007 and 2008, respectively.

Results (Table 1) make it clear that all the weed management practices increased significantly the yield of rice over weedy check. The application of pendimethalin @ 1.0 kg a.i./ha + hand weeding followed by pendimethalin @ 1.0 kg a.i./ha + almix @ 4 g a.i./ha recorded significantly highest biological yield (142.1 and 146.8 q/ha), grain yield (59.8 and 62.5 q/ha), straw yield (83.4 and 85.6 q/ha) and harvest index (0.42 and 0.43) during 2007 and 2008, respectively as compared to rest of the treatments, while the minimum yield and harvest index was recorded with weedy check. The possible reason for this might be effective suppression of weeds without phytotoxicity and consequent higher values of yield contributing characters (panicles/$m^2$, effective spikletets/panicle and test weight). This result can also be attributed to marked improvement in dry matter accumulation, plant height and leaf area index under pendimethalin @ 1.0 kg a.i./ha + hand weeding. Lowest grain yield was recorded under weedy check attributed to vigrous weed growth and consequent reduction in growth of crop plants. The results are in agreement with the findings of Mohan *et al.* (2005).

**Effect on wheat**

The crop establishment techniques of rice had a significant residual effect on yield of subsequent wheat (Table 2). Significantly low yield was obtained in plots where rice was grown in puddled condition compared to unpuddled conditions. This was mainly attributable to relatively greater compaction of soil under puddled condition and its carry over effect to the disadvantage of succeeding wheat. The significantly highest biological yield (111.0 and 117.5 q/ha), grain yield (47.5 and 50.5 q/ha) and straw yield was (63.1 and 67.1 q/ha) recorded under direct seeded rice during 2007-08 and 2008-09, respectively, which found at par with unpuddled transplanting, while the lowest yield was recorded under puddled transplanted rice. Though the well puddled condition provides congenial conditions for rice, it also creates hard pan below the surface restricting the root growth and proliferations of winter season crops in deeper layers. This in turn limits nutrients and moisture availability thus reduction in the grain yield. After direct seeded rice succeeding wheat had greater yield advantage due to favourable soil physical environment as evident by shoot dry matter accumulation, leaf area index and overall growth of crop plants.

The weed management practices of

**Table 2. Biological, grain and straw yield (q/ha); and harvest index of wheat as influenced by residual of crop establishment techniques and weed management practices in rice**

| Treatment | Biological yield | | Grain yield | | Straw yield | | Harvest index | |
|---|---|---|---|---|---|---|---|---|
| | 2007-08 | 2008-09 | 2007-08 | 2008-09 | 2007-08 | 2008-09 | 2007-08 | 2008 09 |
| Crop establishment techniques | | | | | | | | |
| Puddled transplanting (PT) | 97.8 | 102.3 | 41.8 | 43.9 | 55.8 | 58.4 | 0.43 | 0.43 |
| Puddled drum seeding (PDS) | 104.4 | 109.5 | 45.3 | 47.6 | 59.1 | 60.9 | 0.43 | 0.43 |
| Unpuddled transplanting (UPT) | 108.9 | 115.1 | 47.1 | 49.7 | 61.8 | 65.4 | 0.43 | 0.44 |
| Direct seeding (DS) | 111.0 | 117.5 | 47.5 | 50.5 | 63.1 | 67.1 | 0.43 | 0.43 |
| SEm± | 1.04 | 1.24 | 0.60 | 0.72 | 0.59 | 0.67 | 0.03 | 0.05 |
| CD (P=0.05) | 3.6 | 4.3 | 2.1 | 2.5 | 2.0 | 2.3 | NS | NS |
| Weed management practices | | | | | | | | |
| Weedy ($W_0$) | 98.0 | 103.3 | 40.0 | 42.4 | 58.0 | 60.9 | 0.41 | 0.41 |
| Weed-free ($W_1$) | 111.6 | 116.8 | 48.8 | 51.2 | 62.8 | 65.7 | 0.44 | 0.44 |
| Pendimethalin (PE) ($W_2$) | 99.3 | 104.8 | 42.8 | 45.3 | 56.5 | 59.5 | 0.43 | 0.43 |
| Pendimethalin + HW at 30 DAS/DAT ($W_3$) | 106.6 | 112.1 | 46.4 | 48.9 | 60.2 | 63.2 | 0.44 | 0.44 |
| Pendimethalin +Almix at 25 DAS/DAT ($W_4$) | 108.6 | 114.6 | 47.3 | 49.9 | 61.2 | 64.3 | 0.44 | 0.44 |
| Pendimethalin + Fenoxaprop at 25 DAS/DAT ($W_5$) | 108.1 | 113.5 | 47.2 | 49.8 | 61.0 | 64.1 | 0.44 | 0.44 |
| SEm± | 1.03 | 1.11 | 0.55 | 0.59 | 0.64 | 0.70 | 0.03 | 0.04 |
| CD (P=0.05) | 2.9 | 3.2 | 1.6 | 1.7 | 1.8 | 2.0 | NS | NS |

previous rice had significant effect on yield of wheat during both the years (Table 2). The highest biological, grain (108.4 and 114.1 q/ha) and straw yield of wheat were recorded under pendimethalin @ 1.0 kg a.i./ha + almix @ 4 g a.i./ha during both the years. This might be due to a lesser nutrients removal by weeds, which in turn, made more nutrients available to succeeding wheat crop.

**Economics of rice-wheat cropping system**

The highest cost of cultivation of rice-wheat cropping system (₹40945 and 43148/ha) was recorded under puddled transplanted rice, the highest gross returns (104527 and 116357/ha) was recorded under puddled drum seeding, while the highest net returns (65557 and 75812/ha) and B:C ratio (1.76 and

1.95) were recorded with direct seeding of rice during 2007-08 and 2008-09, respectively (Table 3). It might be because of more man-days engaged in puddled transplanted rice.

In rice-wheat cropping system, the highest cost of cultivation (39953 and 41948/ha) was recorded under pendimethalin @ 1.0 kg a.i./ha + hand weeding, while the highest gross returns (107014 and 118537/ha), net returns (69201 and 78926/ha) and B:C ratio (1.83 and 1.98) of rice-wheat cropping system were recorded with pendimethalin @ 1.0 kg a.i./ha + almix @ 4 g a.i./ha, except weed free, 2007-08 and 2008-09 (Table 3). This might be owing to high weed control efficiency (90.24 and 90.82% at harvest) with least man-days engagement and higher grain yield of both rice and wheat under this treatment. The lowest cost of cultivation net returns and B:C ratio were obtained in weedy check treatment because of poor grain yield under severe competition from weeds in rice and the carry-over effect on nutrient exhaustion by perennial weeds in rice to wheat.

Thus, it is imperative from above study that adoption of puddled transplanted rice along with the application of pendimethalin @ 1.0 kg a.i./ha + hand weeding is best agronomic practice to ensure higher yield, maximum net return and B: C ratio of rice. However, the highest yield, net return and B: C ratio of succeeding

**Table 3. Economics of rice-wheat cropping system as influenced by crop establishment techniques and weed management practices**

| Treatment | Cost of cultivation (`/ha) | | Gross return (`/ha) | | Net Return (`/ha) | | B:C ratio | |
|---|---|---|---|---|---|---|---|---|
| | 2007-08 | 2008-09 | 2007-08 | 2008-09 | 2007-08 | 2008-09 | 2007-08 | 2008 09 |
| Crop establishment techniques | | | | | | | | |
| Puddled transplanting (PT) | 40945 | 43148 | 101622 | 111846 | 60677 | 68698 | 1.49 | 1.60 |
| Puddled drum seeding (PDS) | 39595 | 41448 | 104527 | 116357 | 64932 | 74909 | 1.64 | 1.66 |
| Unpuddled transplanting (UPT) | 39545 | 41608 | 100240 | 110659 | 60695 | 69051 | 1.54 | 1.66 |
| Direct seeding (DS) | 37195 | 38908 | 102751 | 114720 | 65557 | 75812 | 1.76 | 1.95 |
| Weed management practices | | | | | | | | |
| Weedy ($W_0$) | 36233 | 38018 | 83720 | 93375 | 47487 | 55357 | 1.31 | 1.42 |
| Weed-free ($W_1$) | 45833 | 48418 | 114295 | 126290 | 68462 | 77872 | 1.50 | 1.56 |
| Pendimethalin (PE) ($W_2$) | 37553 | 39348 | 98961 | 109725 | 61408 | 70377 | 1.64 | 1.76 |
| Pendimethalin + HW at 30 DAS/DAT ($W_3$) | 39953 | 41948 | 105363 | 116459 | 65410 | 74511 | 1.64 | 1.74 |
| Pendimethalin +Almix at 25 DAS/DAT ($W_4$) | 37813 | 39608 | 107014 | 118537 | 69201 | 78929 | 1.83 | 1.98 |
| Pendimethalin + Fenoxaprop at 25 DAS/DAT ($W_5$) | 38533 | 40328 | 104357 | 115988 | 65824 | 75660 | 1.71 | 1.84 |

wheat were recorded under direct seeded rice crop applied with pendimethalin @ 1.0 kg a.i./ha + almix @ 4 g a.i./ha, which also recorded highest net return and B: C ratio of rice-wheat cropping system.

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# OPTIMISING SPACING, SEED RATE, FERTILIZER, SEEDLING AGE AND DATES OF SOWING IN RICE - WHEAT CROPPING SEQUENCE

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## ABSTRACT

Field experiments were conducted at Fertilizer Research Station, Uttaripura of the *C.* S. Azad University of Agriculture and Technology Kanpur to achieve the maximum economic yield of rice-wheat cropping system through the optimising spacing, seed rate, fertilizer need, and seedling age and sowing time during 2006-07 and 2007-08. Results indicated that three week old seedling with spacing of 20X10 cm (50 hill/ $m^2$) and fertilizer dose of $N_{180}$ + $P_2O_{5\ 75}$ + $K_2O_{60}$ + $S_{40}$ + $ZnSO_{4\ 25}$ kg/ha produced maximum yield of hybrid rice to the level of 8.45 t/ha on mean basis. In case of wheat, 125kg/ha seed rate with line sowing in middle of December and fertilized crop with $N_{150}$ + $P_2O_{5\ 60}$ + $K_2O_{40}$ + $S_{40}$ + $ZnSO_{4\ 25}$ kg/ha fetched the maximum yield of PBW 343 variety to the level of 5615 kg/ha on mean basis. The best treatment combination in rice was noted as $V_1$ x $D_1$ x $F_2$ x $S_1$ and wheat was noted as $V_1$ x $D_2$ x $F_2$ x $S_2$.

**Key word :** Spacing, seed rate, fertilizer need, seedling age, dates of sowing, cropping sequence

## INTRODUCTION

Rice-wheat rotation is a dominant cropping system of Uttar Pradesh but the average productivity of this system is very low in comparison to that of Punjab and Haryana. The constraints of low productivity of rice wheat cropping system are not only inadequate and unbalanced fertilization but also are improper agronomic management. Agronomic management is pre-requisite to exploit potential yield and its depends on different region and location and some time even different variety, specific package of practices need to developed to realize full potential yield. Among the various cultural practices, Optimum spacing, seed rate, fertilizer need, seedling age and date of sowing are the most important for yield maximization. Ideal spacing and seed rate are adapted for getting optimum plant population; however, yield potential is not fully exploited mainly due to inadequate plant population. Time of sowing is the most important factor in influencing the yield of rice-wheat cropping system. Timely sowing of rice results in earlier harvest and allows timely sowing of wheat crop. The rice-wheat system productivity was nearly 12 t/ha when about 25 days old rice seedlings were transplanted before end of June. The total rice-wheat system productivity is reduced by more than 40 % when rice was planted after 15 August (Rai, 2006). Keeping these facts in view, the present investigation was under taken.

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## MATERIALS AND METHODS

The experiments were conducted for two consecutive years of 2006-07 and 2007-08 at Fertilizer Research Station Uttaripura, C. S. Azad University of Agriculture and Technology Kanpur on a fixed layout in split plot design with three replications. Treatments were assigning as rice and wheat variety in main plots, spacing in rice and seed rate in wheat in sub plots and different fertilizer rate of rice and wheat, seedling age in rice and date of sowing in wheat in sub-sub plots. Experimental soil was alkaline in reaction (pH 8.20), having EC 0.20 dS/m, OC % 0.38, available N 190 kg/ha, available P 13 kg/ha, available K 200 kg/ha, available S 9.0 kg/ha and available Zn 6 mg/kg. The treatments details are given below :-

(A) Main-plot (Variety)

| | |
|---|---|
| Rice | $V_1$ - PHB 71 (Hybrid) |
| | $V_2$ - Pant12 (HYV) |
| Wheat | $V_1$ -PBW 343 |
| | $V_2$ - Atal (K9644) |

(B) Sub-plots (Spacing in rice and Seed rate in wheat)

| | |
|---|---|
| Rice (spacing) | $S_1$ - 20 cm x 10 cm (50 hills/sqm) |
| | $S_2$ - 20 cm x 15 cm (35 hills/sqm) |
| | $S_3$ - 20 cm x 20 cm (25 hills/sqm) |
| Wheat (Seed rate) | $S_{1}$ - 100 kg/ha. (Line sowing) |
| | $S_2$ - 125 kg/ha. (Line sowing) |
| | $S_3$ - 150 kg/ha. (Broadcasting) |

(C) Sub-Sub plots (Fertilizer, seedling age in rice, sowing date in wheat)

| | |
|---|---|
| Fertilizer (Rice) | $F_1$ - NP ($N_{180}$+$P_2O_{5\ 75}$) |
| | $F_2$ - NPKS Zn ($N_{180}$ + $P_2O_{5\ 75}$ + $K_2O_{60}$ + $S_{40}$ + $ZnSO_{4\ 25}$) |
| | $F_3$ - NPK0S Zn ($N_{180}$ + $P_2O_{5\ 75}$ + $K_2O_0$ + $S_{40}$ + $ZnSO_{4\ 25}$) |
| Fertilizer (Wheat) | $F_1$ - NP ($N_{150}$ + $P_2O_{5\ 60}$) |
| | $F_2$ - NPKS Zn ($N_{150}$ + $P_2O_{5\ 60}$ + $K_2O_{40}$ + $S_{40}$ + $ZnSO_{4\ 25}$) |
| | $F_3$ - NPK0S Zn ($N_{150}$ + $P_2O_{5\ 60}$ + $K_2O_0$ + $S_{40}$ + $ZnSO_{4\ 25}$) |
| Seedling age (rice) | $D_1$ - 3 weeks age |
| | $D_2$ - 5 weeks age |
| Date of sowing (wheat) | $D_1$ - November |
| | $D_2$ - December |

## RESULTS AND DISCUSSION

### Rice

In case of variety, PHB-71 ($V_{1-}$) was found significantly superior to Pant-12 ($V_2$) and gave 22.0% and 20.9% higher yield during 2006 and 2007, respectively. Hybrid vigour in rice is profitably used to increase its productivity by 14-28 % over the available high yielding varieties in India Siddq, (1993) and Pariyani, A.K. and Nayak, K.R., (2004).

Three week seedling of rice ($D_1$) proved superior to five week seedling ($D_2$) showing grain yield of 6206 kg/ha during 2006 and 6013 kg/ha during 2007 as compared to 4498 kg/ha and 4355 kg/ha with five week seedling during both years, respectively (Table-1). The better initial growth coupled with superior yield attributes besides less chaffy grain might be ascribed the reasons for higher yield. These results also confirm the findings of Bali *et al.* (1995) and Channabasappa *et al.* (1998).

Balanced and adequate fertilizer comprising $N_{180}$+$P_2O_{5\ 75}$+$K_2O_{60}$ + $S_{40}$+ $ZnSO_{4\ 25}$ kg/ ha ($F_2$) yielded maximum rice yield to the level of 6012 kg/ha during 2006 and 5869 kg/ha during 2007 (Table-2). Omission of K from the treatment ($F_3$) reduced the yield by 13.0% (600 kg/ha) rice on average basis. The yield of rice significantly increased with application of balanced and adequate fertilizer. Similar findings were reported by Pol *et al.* (2005). Rice crop planted with spacing of 20 cm x 10 cm (50 hills/$m^2$ ($S_1$) yielded maximum to the level of 6103 kg/ha during 2006 and 6007 kg/ha during 2007 (Table-3). The closer plant spacing of 20 cm x 10 cm registered significantly more yield than

**Table 1. Response of variety x date of sowing/seedling age on rice wheat cropping sequence**

| | **Rice (2006)** | | | | | | **Wheat (2006-07)** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Grain (Kg/ha)** | | | **Straw (Kg/ha)** | | | **Grain (Kg/ha)** | | | **Straw (Kg/ha)** | | |
| **V/D** | **$D_1$** | **$D_2$** | **Mean** | **$D_1$** | **$D_2$** | **Mean** | **$D_1$** | **$D_2$** | **Mean** | **$D_1$** | **$D_2$** | **Mean** |
| $V_1$ | 7068 | 4698 | 5883 | 8950 | 7650 | 8300 | 3600 | 4100 | 3850 | 5280 | 5850 | 5565 |
| $V_2$ | 5345 | 4299 | 4822 | 6350 | 5325 | 5837 | 3400 | 3810 | 3605 | 5070 | 5520 | 9295 |
| Mean | 6206 | 4498 | 5352 | 7650 | 6487 | 7068 | 3500 | 3955 | 3727 | 5175 | 5685 | 5430 |
| C.D.5% | V=43 | | | 70 | | | 25 | | | 32 | | |
| | D=43 | | | 75 | | | 30 | | | 38 | | |
| | VxD=60 | | | 90 | | | 45 | | | 48 | | |

| | **Rice (2007)** | | | | | | **Wheat (2007-08)** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Grain (Kg/ha)** | | | **Straw (Kg/ha)** | | | **Grain (Kg/ha)** | | | **Straw (Kg/ha)** | | |
| **V/D** | **$D_1$** | **$D_2$** | **Mean** | **$D_1$** | **$D_2$** | **Mean** | **$D_1$** | **$D_2$** | **Mean** | **$D_1$** | **$D_2$** | **Mean** |
| V/D | $D_1$ | $D_2$ | Mean | $D_1$ | $D_2$ | Mean | $D_1$ | $D_2$ | Mean | $D_1$ | $D_2$ | Mean |
| $V_1$ | 6820 | 4530 | 5675 | 8900 | 7500 | 8200 | 3690 | 4250 | 3970 | 5350 | 5910 | 5630 |
| $V_2$ | 5205 | 4180 | 4693 | 6280 | 5180 | 5730 | 3460 | 3900 | 3680 | 5120 | 5600 | 5360 |
| Mean | 6013 | 4355 | 5184 | 7590 | 6340 | 6965 | 3575 | 4075 | 3825 | 5235 | 5755 | 5495 |
| C.D.5% | V = 48 | | | 76 | | | 29 | | | 34 | | |
| | D = 48 | | | 79 | | | 32 | | | 39 | | |
| | V x D=71 | | | 92 | | | 46 | | | 51 | | |

the wider plant spacing which was mainly due to higher plant population resulting higher number of panicle/$m^2$. The results are accordance with the findings of Geethadevi *et al.* (2000).

Interaction effect of variety and age of seedling revealed that PHB-71 ($V_1$) and three week age seedlings ($D_1$) yielded best as 7068 kg/ha during 2006 and 6820 kg/ha during 2007 (Table-1). Combined effect of variety and fertilizer was significant showing the maximum yield of rice (6527 kg/ha during 2006 and 6418 kg/ha during 2007) with PHB-71 interacted with adequate and balanced fertilizer of $N_{180}$+$P_2O_{5\ 75}$+$K_2O_{60}$+$S_{40}$+$ZnSO_{4\ 25}$ ($F_2$), (Table-2). Interaction of fertilizer x spacing was observed that combination of $F_{---2}$ ($N_{180}$+$P_2O_{5\ 75}$+$K_2O_{60}$+$S_{40}$+$ZnSO_{4\ 25}$ ) x $S_1$ (20 cm x 10 cm) gave maximum yield of 6803 kg/ha and 6910 kg/ha during both years, respectively (Table-3). The results are in the agreement of the findings of Balasubramaniyam and Palaniappan (1991) and Pol *et al.*(2005).The combination of $V_1$ x $D_1$ x $F_2$ produced maximum yield of 7815 kg/ha and 7600 kg/ha during both years, respectively (Table-4). The combined interaction effect of $V_1$ (PHB-71) x $S_1$ (20 cm x 10cm) produced maximum yield of rice as compared to other combination of variety and spacing. Three week old seedling transplanted with closer plant spacing of (20 cm x 10 cm) was revealed that more yield of rice 7217 kg/ha during 2006 and 7100 kg/ha during 2007 (Table-6). The similar results have also been reported by Kumar *et al.* (2002). Among the interaction effect of variety, age of seedling and spacing was showed that three week old seedling of hybrid rice PHB-71 transplanted at closer spacing of 20 cm x 10 cm produced maximum yield (7603 kg/ha during 2006 and 7410 kg/ha during 2007) than the other treatment combination of variety, seedling age and spacing (Table-7). Hybrid rice PHB-71 transplanted at 20 cm x 10 cm plant spacing with application of fertilizer at the rate of $N_{150}$+$P_2O_{5\ 60}$+$K_2O_{40}$+$S_{40}$+$ZnSO_{4\ 25}$ yielded maximum rice as 7081 kg $ha^{-1}$ during 2006 and 6820 kg $ha^{-1}$ during 2007 (Table-8). Combination of $D_1$ x $F_2$ x $S_1$ (3 week seedling age x adequate balanced fertilizer x 20 cm x 10cm spacing) showed maximum rice yield to the level of 8017 kg/ha during 2006 and 7820 kg/ha during 2007 (Table-9). The best treatment combination in rice was noted as $V_1$ x $D_1$ x $F_2$ x S1 i.e. PHB-71 with three week seedling age planted at the spacing of 20cm x 10cm and fertilizer with N180 x $P_2O_5$ 75 + $K_2O$ 60 +S40 + $ZnSO_4$ 25 kg $ha^{-1}$ which yielded maximum to the level of 8510 kg $ha^{-1}$ during 2006 and 8410 kg during 2007 (Table-10) & Fig.-1.

## Wheat

Wheat variety PBW 343 ($V_1$) yielded 3850 kg/ha and 3970 kg/ha as compared to 3605 kg/ha and 3680 kg/ha for Atal ($V_{2-}$) during rabi season of 2006-07 and 2007-08 respectively (Table-1). The percentage increase in yield of PBW 343 over Atal was noted as 6.8% during first year and 7.8% during second year. Date of sowing in wheat revealed that December sowing ($D_2$) showed more yield (3955 kg/ha) than November sowing (3500 kg/ha) noted during 2006-07 (Table-1). Similar finding was noted during 2007-08 depicting yield level of 4075 kg/ha in December sowing ($D_2$) and 3575 kg/ha in November sowing ($D_1$). Similar trend was noted for straw yield also (Table-1). Effect of different levels of fertilizer on wheat indicated that fertilizer doses of $N_{150}$ + $P_2O_{5\ 60}$+ $K_2O_{\ 40}$+ $S_{40}$ + Zn $SO_4.7H_2O_{\ 25}$ kg/ha ($F_2$) yielded

**Table 2. Response of variety x fertilizer on rice wheat cropping sequence**

| | Rice (2006) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Grain (Kg/ha) | | | | Straw (Kg/ha) | | | |
| **V/F** | **$F_1$** | **$F_2$** | **$F_3$** | **Mean** | **$F_1$** | **$F_2$** | **$F_3$** | **Mean** |
| $V_1$ | 5186 | 6527 | 5936 | 5883 | 6275 | 7765 | 7716 | 7252 |
| $V_2$ | 4422 | 5497 | 4517 | 4812 | 5527 | 6490 | 5460 | 5825 |
| Mean | 4804 | 6012 | 5226 | 5347 | 5901 | 7127 | 6588 | 6538 |
| C.D. | F=46 | | | | 58 | | | |
| | FxV=65 | | | | 76 | | | |

| | Wheat (2006-07) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Grain (Kg/ha) | | | | Straw (Kg/ha) | | | |
| **V/F** | **$F_1$** | **$F_2$** | **$F_3$** | **Mean** | **$F_1$** | **$F_2$** | **$F_3$** | **Mean** |
| $V_1$ | 3950 | 5810 | 5320 | 5026.7 | 5900 | 8590 | 8010 | 7500 |
| $V_2$ | 3520 | 4250 | 3980 | 3916.6 | 5030 | 6050 | 6000 | 5693.3 |
| Mean | 3735 | 5030 | 4650 | 4476.6 | 5465 | 7320 | 7005 | 6596.7 |
| C.D. | F=38 | | | | 48 | | | |
| | FxV=56 | | | | 62 | | | |

| | Rice (2007) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Grain (Kg/ha) | | | | Straw (Kg/ha) | | | |
| **V/F** | **$F_1$** | **$F_2$** | **$F_3$** | **Mean** | **$F_1$** | **$F_2$** | **$F_3$** | **Mean** |
| $V_1$ | 5100 | 6418 | 5850 | 5789 | 6300 | 7910 | 7780 | 7330 |
| $V_2$ | 4314 | 5320 | 4410 | 4681 | 6520 | 5510 | 5820 | 5950 |
| Mean | 4707 | 5869 | 5130 | 5235 | 6410 | 6710 | 6800 | 6640 |
| C.D. | F = 53 | | | | 56 | | | |
| | F x V =74 | | | | 77 | | | |

| | Wheat (2007-08) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Grain (Kg/ha) | | | | Straw (Kg/ha) | | | |
| **V/F** | **$F_1$** | **$F_2$** | **$F_3$** | **Mean** | **$F_1$** | **$F_2$** | **$F_3$** | **Mean** |
| $V_1$ | 4010 | 5900 | 5390 | 5100 | 6010 | 8600 | 8050 | 7553 |
| $V_2$ | 3650 | 4320 | 4020 | 3997 | 6020 | 6100 | 6250 | 6123 |
| Mean | 3830 | 5110 | 4705 | 4548 | 6015 | 7350 | 7150 | 6838 |
| C.D. | F =36 | | 43 | | | | | |
| | F x V =58 | | | 60 | | | | |

**Table 3. Response of fertilizer x spacing/seed rate on rice wheat cropping sequence**

| FxS | Rice (2006) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Grain (Kg/ha) | | | | Straw (Kg/ha) | | | |
| VXS | $S_1$ | $S_2$ | $S_3$ | Mean | $S_1$ | $S_2$ | $S_3$ | Mean |
| $F_1$ | 5347 | 4884 | 6161 | 5464 | 6680 | 6105 | 7390 | 6725 |
| $F_2$ | 6803 | 6092 | 4949 | 5948 | 8092 | 7680 | 5950 | 7240 |
| $F_3$ | 6161 | 5146 | 4581 | 5296 | 7590 | 6125 | 5610 | 6441 |
| Mean | 6103 | 5374 | 5230 | 5569 | 7454 | 6636 | 6316 | 6802 |
| C.D. | S=48 | | | | 60 | | | |
| | SxF=84 | | | | 92 | | | |

| FxS | Wheat (2006-07) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Grain (Kg/ha) | | | | Straw (Kg/ha) | | | |
| VXS | $S_1$ | $S_2$ | $S_3$ | Mean | $S_1$ | $S_2$ | $S_3$ | Mean |
| $F_1$ | 3500 | 3920 | 3848 | 3756 | 5300 | 5920 | 5620 | 5613 |
| $F_2$ | 4580 | 4210 | 4200 | 4330 | 6520 | 6080 | 6225 | 6275 |
| $F_3$ | 4210 | 4590 | 4430 | 4410 | 6150 | 6670 | 6200 | 6340 |
| Mean | 4096 | 4240 | 4159 | 4165 | 5990 | 6223 | 6015 | 6076 |
| C.D. | S=39 | | | | 45 | | | |
| | SxF=72 | | | | 78 | | | |

| FxS | Rice (2007) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Grain (Kg/ha) | | | | Straw (Kg/ha) | | | |
| VXS | $S_1$ | $S_2$ | $S_3$ | Mean | $S_1$ | $S_2$ | $S_3$ | Mean |
| 1 | $S_2$ | $S_3$ | Mean | | | | | |
| $F_1$ | 5290 | 4750 | 6010 | 5350 | 6620 | 6200 | 7350 | 6723 |
| $F_2$ | 6910 | 6770 | 4820 | 6150 | 7910 | 7600 | 6000 | 7170 |
| $F_3$ | 6100 | 5000 | 4512 | 5174 | 7610 | 6200 | 5750 | 6520 |
| Mean | 6007 | 5553 | 5114 | 5558 | 7380 | 6666 | 6366 | 6804 |
| C.D. | S = 48 | | | | 57 | | | |
| | S x F =80 | | | | 88 | | | |

| FxS | Wheat (2007-08) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Grain (Kg/ha) | | | | Straw (Kg/ha) | | | |
| VXS | $S_1$ | $S_2$ | $S_3$ | Mean | $S_1$ | $S_2$ | $S_3$ | Mean |
| $F_1$ | 3610 | 3980 | 3920 | 3836 | 5420 | 6050 | 5680 | 5716 |
| $F_2$ | 4650 | 4350 | 4290 | 4430 | 6640 | 6220 | 6350 | 6403 |
| $F_3$ | 4300 | 4700 | 4460 | 4486 | 6200 | 6690 | 6220 | 6370 |
| Mean | 4186 | 4343 | 4223 | 4250 | 6086 | 6320 | 6083 | 6163 |
| C.D. | S=39 | | | | 47 | | | |
| | S x F = 68 | | | | 75 | | | |

**Table 4. Response of fertilizer x variety x date of sowing/seedling age on rice wheat cropping sequence**

| F/VD | Rice (2006) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Grain (Kg/ha) | | | | | Straw (Kg/ha) | | | | |
| | $V_1D_1$ | $V_1D_2$ | $V_2D_1$ | $V_2D_2$ | Mean | $V_1D_1$ | $V_1D_2$ | $V_2D_1$ | $V_2D_2$ | Mean |
| F1 | 6072 | 4300 | 4943 | 3902 | 4804 | 8150 | 7000 | 7590 | 6000 | 7185 |
| F2 | 7815 | 5237 | 6227 | 4768 | 6011 | 10025 | 6890 | 8015 | 7880 | 8052 |
| F3 | 7315 | 4557 | 4868 | 4168 | 5227 | 9410 | 5980 | 6390 | 5630 | 6852 |
| Mean | 7067 | 4698 | 5346 | 4279 | 5347 | 9195 | 6623 | 7331 | 6303 | 7363 |
| C.D. | VxDXF=92 | | | | | 108 | | | | |

| F/VD | Wheat (2006-07) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Grain (Kg/ha) | | | | | Straw (Kg/ha) | | | | |
| | $V_1D_1$ | $V_1D_2$ | $V_2D_1$ | $V_2D_2$ | Mean | $V_1D_1$ | $V_1D_2$ | $V_2D_1$ | $V_2D_2$ | Mean |
| F1 | 3980 | 4020 | 3900 | 4000 | 3975 | 5800 | 6025 | 5725 | 6280 | 5957 |
| F2 | 5520 | 5150 | 4180 | 4550 | 4850 | 7610 | 7280 | 6090 | 7025 | 7001 |
| F3 | 5215 | 5010 | 4310 | 4280 | 4703 | 7180 | 7250 | 6220 | 6390 | 6835 |
| Mean | 4905 | 4726 | 4130 | 4776 | 4509 | 6963 | 6851 | 6011 | 6565 | 6598 |
| C.D. | VXDXF=65 | | | | | 76 | | | | |

| F/VD | Rice (2007) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Grain (Kg/ha) | | | | | Straw (Kg/ha) | | | | |
| | $V_1D_1$ | $V_1D_2$ | $V_2D_1$ | $V_2D_2$ | Mean | $V_1D_1$ | $V_1D_2$ | $V_2D_1$ | $V_2D_2$ | Mean |
| F1 | 5900 | 4210 | 4830 | 3850 | 4697 | 8200 | 7120 | 7600 | 6080 | 7250 |
| F2 | 7600 | 5110 | 6125 | 4600 | 5858 | 10000 | 6900 | 8020 | 7950 | 8217 |
| F3 | 7210 | 4500 | 4750 | 4100 | 5140 | 9500 | 6020 | 6420 | 5700 | 6910 |
| Mean | 6903 | 4606 | 5235 | 4183 | 5231 | 9233 | 6680 | 7347 | 6576 | 7459 |
| C.D. | V x D x F | 90 | | | | 110 | | | | |

| F/VD | Wheat (2007-08) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Grain (Kg/ha) | | | | | Straw (Kg/ha) | | | | |
| | $V_1D_1$ | $V_1D_2$ | $V_2D_1$ | $V_2D_2$ | Mean | $V_1D_1$ | $V_1D_2$ | $V_2D_1$ | $V_2D_2$ | Mean |
| F1 | 4070 | 4110 | 4050 | 4130 | 4090 | 5860 | 6100 | 5810 | 6320 | 6022 |
| F2 | 5600 | 5220 | 4300 | 4590 | 4927 | 7690 | 7350 | 6180 | 7100 | 7080 |
| F3 | 5310 | 5100 | 4280 | 4340 | 4757 | 7210 | 7300 | 6200 | 636 | 6767 |
| Mean | 4973 | 4810 | 4210 | 4353 | 4591 | 6920 | 4916 | 6063 | 6593 | 6623 |
| C.D. | V x D x F | 68 | | | | 81 | | | | |

**Table 5. Response of variety x spacing/seed rate on rice wheat cropping sequence**

| V/S | Rice (2006) | | | | | |
|---|---|---|---|---|---|---|
| | Grain (Kg/ha) | | | Straw (Kg/ha) | | |
| | V1 | V2 | Mean | V1 | V2 | Mean |
| S1 | 6419 | 5788 | 6103 | 7580 | 7820 | 7700 |
| S2 | 5812 | 4797 | 5304 | 7165 | 6235 | 6700 |
| S3 | 5416 | 3852 | 4634 | 6800 | 5250 | 6025 |
| Mean | 5882 | 4812 | 534 | 7181 | 6435 | 6808 |
| CD 5% | VxS=68 | | | 90 | | |

| V/S | Wheat (2006-07) | | | | | |
|---|---|---|---|---|---|---|
| | Grain (Kg/ha) | | | Straw (Kg/ha) | | |
| | V1 | V2 | Mean | V1 | V2 | Mean |
| S1 | 4220 | 3980 | 4100 | 6190 | 5810 | 6000 |
| S2 | 4890 | 4130 | 4510 | 7025 | 6200 | 6612 |
| S3 | 4400 | 3900 | 4150 | 6290 | 5825 | 6057 |
| Mean | 4503 | 4003 | 4253 | 6501 | 5945 | 6223 |
| CD 5% | VxS=53 | | | 62 | | |

| V/S | Rice (2007) | | | | | |
|---|---|---|---|---|---|---|
| | Grain (Kg/ha) | | | Straw (Kg/ha) | | |
| | V1 | V2 | Mean | V1 | V2 | Mean |
| S1 | 6250 | 5670 | 5960 | 7420 | 7690 | 7555 |
| S2 | 5670 | 4700 | 5185 | 7100 | 6200 | 6650 |
| S3 | 5300 | 3770 | 4535 | 6650 | 5210 | 5930 |
| Mean | 5740 | 4713 | 5226 | 7056 | 6366 | 6711 |
| CD 5% | V x S | 65 | | 86 | | |

| V/S | Wheat (2007-08) | | | | | |
|---|---|---|---|---|---|---|
| | Grain (Kg/ha) | | | Straw (Kg/ha) | | |
| | V1 | V2 | Mean | V1 | V2 | Mean |
| S1 | 4370 | 4076 | 4223 | 6250 | 5900 | 6075 |
| S2 | 4950 | 4200 | 4575 | 7090 | 6300 | 6695 |
| S3 | 4510 | 3990 | 4250 | 6320 | 5850 | 6085 |
| Mean | 4610 | 4088 | 4349 | 6553 | 6016 | 6285 |
| CD 5% | V x S =55 | | | 63 | | |

**Table 6. Response of date of sowing/seedling age X spacing/seed rate on rice wheat cropping sequence**

| **D/S** | **Rice (2006)** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Grain (Kg/ha)** | | | | **Straw (Kg/ha)** | | | |
| | **$S_1$** | **$S_2$** | **$S_3$** | **Mean** | **$S_1$** | **$S_2$** | **$S_3$** | **Mean** |
| $D_1$ | 7217 | 6202 | 5202 | 6207 | 9590 | 8020 | 7000 | 8203 |
| $D_2$ | 4991 | 4408 | 4066 | 4487 | 6220 | 6000 | 5750 | 5990 |
| Mean | 6104 | 5305 | 4634 | 5347 | 7905 | 7010 | 6375 | 7096 |
| C.D. | DxS=68 | | | | 85 | | | |

| **D/S** | **Wheaat (2006-07)** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Grain (Kg/ha)** | | | | **Straw (Kg/ha)** | | | |
| | **$S_1$** | **$S_2$** | **$S_3$** | **Mean** | **$S_1$** | **$S_2$** | **$S_3$** | **Mean** |
| | $D_1$ | 4025 | 4210 | 4120 | 4118 | 5900 | 6215 | 6350 |
| 6155 | | | | | | | | |
| $D_2$ | 4280 | 4810 | 4650 | 4580 | 6390 | 7025 | 6890 | 6768 |
| Mean | 4152 | 4510 | 4385 | 4349 | 4145 | 6620 | 6620 | 6461 |
| C.D. | DxS=62 | | | | 65 | | | |

| **D/S** | **Rice (2007)** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Grain (Kg/ha)** | | | | **Straw (Kg/ha)** | | | |
| | **$S_1$** | **$S_2$** | **$S_3$** | **Mean** | **$S_1$** | **$S_2$** | **$S_3$** | **Mean** |
| $D_1$ | 7100 | 6120 | 5140 | 61200 | 9600 | 8050 | 7120 | 8256 |
| $D_2$ | 4825 | 4320 | 3980 | 4375 | 6300 | 6050 | 5800 | 6050 |
| Mean | 5963 | 5220 | 4560 | 5247 | 7950 | 7050 | 6460 | 7153 |
| C.D. | D x S = | 64 | | | | | | |

| **D/S** | **Wheat (2007-08)** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Grain (Kg/ha)** | | | | **Straw (Kg/ha)** | | | |
| | **$S_1$** | **$S_2$** | **$S_3$** | **Mean** | **$S_1$** | **$S_2$** | **$S_3$** | **Mean** |
| $D_1$ | 4180 | 4300 | 4250 | 4243 | 6010 | 6300 | 6390 | 6233 |
| $D_2$ | 4370 | 4900 | 4700 | 4656 | 6400 | 7080 | 6900 | 6793 |
| Mean | 4275 | 4600 | 4475 | 4450 | 6205 | 6690 | 6645 | 6513 |
| C.D. | D x S = | 64 | | | 69 | | | |

**Table 7. Response of variety x date of sowing/seedling age x spacing/seed rate on rice wheat cropping sequence**

| S/VD | Rice (2006) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Grain (Kg/ha) | | | | | Straw (Kg/ha) | | | | |
| | $V_1D_1$ | $V_1D_2$ | $V_2D_1$ | $V_2D_2$ | Mean | $V_1D_1$ | $V_1D_2$ | $V_2D_1$ | $V_2D_2$ | Mean |
| $S_1$ | 7603 | 5235 | 6830 | 4747 | 6103 | 9800 | 6990 | 8810 | 6250 | 7962 |
| $S_2$ | 7020 | 4605 | 5383 | 4212 | 5305 | 9270 | 6690 | 7085 | 5600 | 7158 |
| $S_3$ | 6578 | 4254 | 3825 | 3871 | 4633 | 8625 | 6500 | 5070 | 5150 | 6336 |
| Mean | 7067 | 4698 | 5346 | 4279 | 5347 | 9231 | 6723 | 6988 | 5666 | 7152 |
| C.D. | VxDxS=97 | | | | | 108 | | | | |

| S/VD | Wheat (2006-07) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Grain (Kg/ha) | | | | | Straw (Kg/ha) | | | | |
| | $V_1D_1$ | $V_1D_2$ | $V_2D_1$ | $V_2D_2$ | Mean | $V_1D_1$ | $V_1D_2$ | $V_2D_1$ | $V_2D_2$ | Mean |
| $S_1$ | 5025 | 5390 | 4500 | 3980 | 4723 | 6990 | 7510 | 6525 | 5800 | 6706 |
| $S_2$ | 4810 | 5510 | 4800 | 4200 | 4830 | 6600 | 7720 | 6650 | 6280 | 6812 |
| $S_3$ | 4625 | 5000 | 4512 | 4030 | 4541 | 6500 | 7215 | 6580 | 6000 | 6513 |
| Mean | 4820 | 5300 | 4604 | 4070 | 4698 | 6696 | 7481 | 6585 | 6026 | 6697 |
| C.D. | VxDxS=70 | | | | | 74 | | | | |

| S/VD | Rice (2007) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Grain (Kg/ha) | | | | | Straw (Kg/ha) | | | | |
| | $V_1D_1$ | $V_1D_2$ | $V_2D_1$ | $V_2D_2$ | Mean | $V_1D_1$ | $V_1D_2$ | $V_2D_1$ | $V_2D_2$ | Mean |
| $S_1$ | 7410 | 5120 | 6710 | 4700 | 5985 | 9600 | 6720 | 8650 | 6100 | 7767 |
| $S_2$ | 6800 | 4500 | 5250 | 4100 | 5162.5 | 9200 | 6700 | 7000 | 5680 | 7145 |
| $S_3$ | 6480 | 4120 | 3720 | 3750 | 4517.5 | 8600 | 6610 | 5220 | 5350 | 6445 |
| Mean | 6896 | 4580 | 5226 | 4183 | 5221 | 9133 | 6676 | 6956 | 5710 | 7119 |
| C.D. | VxDxS=94 | | | | 110 | | | | | |

| S/VD | Wheat (2007-08) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Grain (Kg/ha) | | | | | Straw (Kg/ha) | | | | |
| | $V_1D_1$ | $V_1D_2$ | $V_2D_1$ | $V_2D_2$ | Mean | $V_1D_1$ | $V_1D_2$ | $V_2D_1$ | $V_2D_2$ | Mean |
| $S_1$ | 5210 | 5450 | 4590 | 4070 | 4830 | 7100 | 7680 | 6610 | 5925 | 6828.75 |
| $S_2$ | 4920 | 5600 | 4820 | 4310 | 4912.5 | 6710 | 7800 | 6650 | 6390 | 6887.50 |
| $S_3$ | 4730 | 5120 | 4590 | 4090 | 4632.5 | 6650 | 7300 | 6580 | 6080 | 6652.50 |
| Mean | 4953.33 | 5390 | 4666.66 | 4156.66 | 4791.7 | 6820 | 7593.33 | 6613.33 | 6131.66 | 6789.6 |
| C.D. | VxSxD=75 | | | | 81 | | | | | |

**Table 8. Response of variety x fertilizer x spacing/seed rate on rice wheat cropping sequence**

**Rice (2006)**

| | Grain (Kg/ha) | | | | | | | Straw (Kg/ha) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SDF | $V_1F_1$ | $V_1F_2$ | $V_1F_3$ | $V_2F_1$ | $V_2F_2$ | $V_2F_3$ | Mean | $V_1F_1$ | $V_1F_2$ | $V_1F_3$ | $V_2F_1$ | $V_2F_2$ | $V_2F_3$ | Mean |
| $S_1$ | 5605 | 7081 | 6471 | 5090 | 6422 | 5851 | 6103 | 7847 | 10190 | 8850 | 7010 | 8250 | 7825 | 8328 |
| $S_2$ | 5158 | 6407 | 5872 | 4610 | 5777 | 4005 | 5304 | 7324 | 8950 | 7910 | 6820 | 7225 | 5890 | 7353 |
| $S_3$ | 4795 | 5987 | 5465 | 3566 | 4292 | 3695 | 4633 | 7190 | 8520 | 7525 | 6025 | 6025 | 5700 | 6830 |
| Mean | 5186 | 6525 | 5936 | 4422 | 5497 | 4517 | 5347 | 7453 | 9220 | 8095 | 6618 | 6167 | 6472 | 7504 |
| CD5% | 97 | | | | | | | 109 | | | | | | |

**Wheat (2006-07)**

| | Grain (Kg/ha) | | | | | | | Straw (Kg/ha) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SDF | $V_1F_1$ | $V_1F_2$ | $V_1F_3$ | $V_2F_1$ | $V_2F_2$ | $V_2F_3$ | Mean | $V_1F_1$ | $V_1F_2$ | $V_1F_3$ | $V_2F_1$ | $V_2F_2$ | $V_2F_3$ | Mean |
| $S_1$ | 4011 | 5224 | 4800 | 3600 | 4290 | 4110 | 4339 | 5980 | 7500 | 6920 | 5210 | 6200 | 6050 | 6310 |
| $S_2$ | 4100 | 5500 | 5000 | 3810 | 4400 | 4250 | 4510 | 6200 | 7810 | 7290 | 5390 | 6320 | 6190 | 6533 |
| $S_3$ | 4000 | 5080 | 4610 | 3700 | 4125 | 4015 | 4255 | 6050 | 7280 | 6725 | 5200 | 5925 | 5810 | 6165 |
| Mean | 4037 | 5268 | 4803 | 3703 | 4271 | 4125 | 4368 | 6076 | 7530 | 6978 | 5267 | 6148 | 6017 | 6336 |
| CD5% | 76 | | | | | | | 80 | | | | | | |

**Rice (2007)**

| | Grain (Kg/ha) | | | | | | | Straw (Kg/ha) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SDF | $V_1F_1$ | $V_1F_2$ | $V_1F_3$ | $V_2F_1$ | $V_2F_2$ | $V_2F_3$ | Mean | $V_1F_1$ | $V_1F_2$ | $V_1F_3$ | $V_2F_1$ | $V_2F_2$ | $V_2F_3$ | Mean |
| $S_1$ | 5470 | 6820 | 6470 | 5020 | 6310 | 590 | 5980 | 7800 | 10050 | 8810 | 6820 | 8150 | 7700 | 8221 |
| $S_2$ | 5100 | 6328 | 5700 | 4580 | 5700 | 3920 | 5221 | 7300 | 8900 | 7820 | 6910 | 7190 | 5820 | 7323 |
| $S_3$ | 4710 | 5900 | 5370 | 3600 | 4200 | 3600 | 4563 | 200 | 8600 | 7600 | 6120 | 6000 | 5700 | 6870 |
| Mean | 5093 | 6349 | 5846 | 4400 | 5403 | 4436 | 5254 | 7433 | 9183 | 8076 | 6616 | 7113 | 6406 | 7471 |
| CD5% | | 92 | | | | | | 108 | | | | | | |

**Wheat (2007-08)**

| | Grain (Kg/ha) | | | | | | | Straw (Kg/ha) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SDF | $V_1F_1$ | $V_1F_2$ | $V_1F_3$ | $V_2F_1$ | $V_2F_2$ | $V_2F_3$ | Mean | $V_1F_1$ | $V_1F_2$ | $V_1F_3$ | $V_2F_1$ | $V_2F_2$ | $V_2F_3$ | Mean |
| $S_1$ | 4150 | 5320 | 4910 | 3690 | 4310 | 4190 | 4428 | 6010 | 7600 | 7000 | 5300 | 6250 | 6150 | 6385 |
| $S_2$ | 4200 | 5600 | 5150 | 3900 | 4470 | 4300 | 4603 | 6320 | 4800 | 7250 | 5420 | 6310 | 6200 | 6550 |
| $S_3$ | 4110 | 5150 | 4700 | 3750 | 4200 | 4100 | 4335 | 6180 | 7310 | 6800 | 5300 | 5900 | 5900 | 6231 |
| Mean | 4153 | 5356 | 4920 | 3780 | 4326 | 4196 | 4455 | 6170 | 7570 | 7016 | 5340 | 6153 | 6083 | 6388 |
| CD5% | | 82 | | | | | | 87 | | | | | | |

**Table 9. Response of date of sowing/seedling age x fertilizer x spacing/seed rate on rice wheat cropping sequence**

| | Rice (2006) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grain (Kg/ha) | | | | | | | Straw (Kg/ha) | | | | | | |
| **S/DF** | $D_1F_1$ | $D_1F_2$ | $D_1F_3$ | $D_2F_1$ | $D_2F_2$ | $D_2F_3$ | **Mean** | $D_1F_1$ | $D_1F_2$ | $D_1F_3$ | $D_2F_1$ | $D_2F_2$ | $D_2F_3$ | **Mean** |
| $S_1$ | 6225 | 8017 | 7407 | 4470 | 5587 | 4915 | 6103 | 8320 | 10225 | 9890 | 6025 | 7210 | 6830 | 8083 |
| $S_2$ | 5735 | 7297 | 5572 | 4032 | 4887 | 4305 | 5305 | 8020 | 10190 | 7210 | 6090 | 7025 | 6380 | 7486 |
| $S_3$ | 4662 | 5747 | 5295 | 3806 | 4532 | 3865 | 3634 | 6725 | 7510 | 7180 | 6220 | 6635 | 6050 | 6720 |
| Mean | 5507 | 7020 | 6091 | 4102 | 5002 | 4361 | 5347 | 7688 | 9308 | 8093 | 6111 | 6956 | 6420 | 7429 |
| CD5% | DxFxS =97 | | | | | | 105 | | | | | | | |

| | Wheat (2006-07) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grain (Kg/ha) | | | | | | | Straw (Kg/ha) | | | | | | |
| **SDF** | $D_1F_1$ | $D_1F_2$ | $D_1F_3$ | $D_2F_1$ | $D_2F_2$ | $D_2F_3$ | **Mean** | $D_1F_1$ | $D_1F_2$ | $D_1F_3$ | $D_2F_1$ | $D_2F_2$ | $D_2F_3$ | **Mean** |
| $S_1$ | 4080 | 5625 | 5210 | 4190 | 5810 | 5500 | 5869 | 5925 | 7920 | 7500 | 6025 | 8520 | 7625 | 7252 |
| $S_2$ | 4100 | 5830 | 5390 | 4150 | 5800 | 5400 | 5111 | 6090 | 8500 | 7630 | 6000 | 8690 | 7280 | 7365 |
| $S_3$ | 4000 | 5080 | 4750 | 4030 | 5090 | 5000 | 4658 | 5800 | 7410 | 6800 | 5930 | 7380 | 7250 | 6761 |
| Mean | 4060 | 4511 | 5116 | 4123 | 5566 | 5300 | 4946 | 5938 | 7943 | 7310 | 5985 | 8196 | 7385 | 7126 |
| CD 5% | DxFxS= 68 | | | | | | 75 | | | | | | | |

| | Rice (2007) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grain (Kg/ha) | | | | | | | Straw (Kg/ha) | | | | | | |
| **S/DF** | $D_1F_1$ | $D_1F_2$ | $D_1F_3$ | $D_2F_1$ | $D_2F_2$ | $D_2F_3$ | **Mean** | $D_1F_1$ | $D_1F_2$ | $D_1F_3$ | $D_2F_1$ | $D_2F_2$ | $D_2F_3$ | **Mean** |
| $S_1$ | 6115 | 7820 | 7300 | 4320 | 5450 | 4800 | 5967.5 | 8390 | 10250 | 9800 | 6100 | 7210 | 6830 | 8096 |
| $S_2$ | 5650 | 7180 | 5580 | 4000 | 4800 | 4200 | 5235 | 810 | 10200 | 7250 | 6100 | 7110 | 6400 | 7526 |
| $S_3$ | 4510 | 5620 | 5200 | 3720 | 4500 | 3820 | 4561 | 6800 | 7550 | 7200 | 6250 | 6700 | 6100 | 6766 |
| 6100 | 5425 | 6873 | 6026 | 4013 | 4916 | 4273 | 5254 | 7763 | 9333 | 8083 | 6150 | 7006 | 6443 | 7463 |
| CD 5% | DxFxS= 91 | | | | | | 108 | | | | | | | |

| | Wheat (2007-08) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grain (Kg/ha) | | | | | | | Straw (Kg/ha) | | | | | | |
| **SDF** | $D_1F_1$ | $D_1F_2$ | $D_1F_3$ | $D_2F_1$ | $D_2F_2$ | $D_2F_3$ | **Mean** | $D_1F_1$ | $D_1F_2$ | $D_1F_3$ | $D_2F_1$ | $D_2F_2$ | $D_2F_3$ | **Mean** |
| $S_1$ | 4210 | 5700 | 5320 | 4250 | 5890 | 5590 | 5160 | 6010 | 7880 | 7600 | 6190 | 8600 | 7700 | 7330 |
| $S_2$ | 4300 | 5900 | 5450 | 4200 | 5920 | 8500 | 5211 | 6100 | 8450 | 7680 | 6100 | 8710 | 7310 | 7391 |
| $S_3$ | 4190 | 5200 | 4820 | 4100 | 5150 | 5080 | 4756 | 5750 | 7420 | 6910 | 6010 | 7400 | 7400 | 6815 |
| Mean | 4233 | 5600 | 5196 | 4183 | 5653 | 5390 | 5042 | 5353 | 7916 | 4396 | 6100 | 8236 | 7470 | 7178 |
| CD 5% | DxFxS =71 | | | | | | 77 | | | | | | | |

**Table 10. Response of variety x date of sowing/seedling age x fertilizer x spacing/seed rate on rice wheat cropping sequence**

| FS/VD | Rice (2006) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Grain (Kg/ha) | | | | | Straw (Kg/ha) | | | | |
| | $V_1D_1$ | $V_1D_2$ | $V_2D_1$ | $V_2D_2$ | Mean | $V_1D_1$ | $V_1D_2$ | $V_2D_1$ | $V_2D_2$ | Mean |
| $F_1S_1$ | 6500 | 4710 | 5950 | 4230 | 5347 | 9050 | 6250 | 8280 | 6230 | 7452 |
| $F_1S_2$ | 6100 | 4215 | 5370 | 3850 | 4883 | 8230 | 5980 | 7560 | 6000 | 6942 |
| $F_1S_3$ | 5615 | 3975 | 3510 | 3625 | 4181 | 7525 | 6030 | 5990 | 5825 | 6192 |
| $F_2S_1$ | 8510 | 5855 | 7525 | 5320 | 6802 | 11080 | 8025 | 10050 | 7010 | 9041 |
| $F_2S_2$ | 7715 | 5100 | 6880 | 4675 | 6092 | 10500 | 7525 | 9280 | 6525 | 8457 |
| $F_2S_3$ | 7220 | 4755 | 4275 | 4310 | 5140 | 9980 | 7835 | 6350 | 6210 | 7593 |
| $F_3S_1$ | 7800 | 5140 | 7015 | 4690 | 6161 | 10890 | 7610 | 9800 | 6580 | 8720 |
| $F_3S_2$ | 7245 | 4500 | 3900 | 4510 | 4938 | 9850 | 6520 | 6210 | 6020 | 7150 |
| $F_3S_3$ | 6900 | 4030 | 3690 | 3700 | 4580 | 9230 | 6035 | 5910 | 5325 | 6625 |
| Mean | 7067 | 4698 | 5346 | 4279 | 4580 | 9592 | 6867 | 7647 | 6191 | 7575 |
| CD | VxDxFxS=167 | | | | 192 | | | | | |

| FS/VD | Wheat (2007) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Grain (Kg/ha) | | | | | Straw (Kg/ha) | | | | |
| | $V_1D_1$ | $V_1D_2$ | $V_2D_1$ | $V_2D_2$ | Mean | $V_1D_1$ | $V_1D_2$ | $V_2D_1$ | $V_2D_2$ | Mean |
| $F_1S_1$ | 3925 | 4020 | 3510 | 3680 | 3783 | 5790 | 5900 | 5210 | 5300 | 5550 |
| $F_1S_2$ | 4090 | 4200 | 3600 | 3650 | 3885 | 6000 | 6080 | 5255 | 5450 | 5696 |
| $F_1S_3$ | 3980 | 4100 | 3610 | 3600 | 3822 | 6200 | 6100 | 5125 | 5200 | 5656 |
| $F_2S_1$ | 5010 | 5200 | 4280 | 4390 | 4720 | 7290 | 7320 | 6390 | 6350 | 6837 |
| $F_2S_2$ | 5315 | 5580 | 4600 | 4725 | 5055 | 7520 | 7790 | 6550 | 6720 | 7145 |
| $F_2S_3$ | 5125 | 5210 | 4415 | 4500 | 4812 | 7260 | 7300 | 6295 | 6580 | 6858 |
| $F_3S_1$ | 5000 | 5125 | 4230 | 4350 | 4676 | 7025 | 7120 | 6250 | 6380 | 6703 |
| $F_3S_2$ | 5120 | 5200 | 4380 | 4450 | 4785 | 7500 | 7520 | 6390 | 6610 | 7005 |
| $F_3S_3$ | 5000 | 5390 | 4060 | 4350 | 4700 | 7250 | 7620 | 5910 | 6320 | 6775 |
| Mean | 4729 | 4891 | 4076 | 4188 | 4471 | 6875 | 6972 | 5930 | 6101 | 6469 |
| CD | VxDxFxS=142 | | | | 158 | | | | | |

| FS/VD | Rice (2007) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Grain (Kg/ha) | | | | | Straw (Kg/ha) | | | | |
| | $V_1D_1$ | $V_1D_2$ | $V_2D_1$ | $V_2D_2$ | Mean | $V_1D_1$ | $V_1D_2$ | $V_2D_1$ | $V_2D_2$ | Mean |
| $F_1S_1$ | 6320 | 4600 | 5800 | 4100 | 5205 | 8920 | 6200 | 8200 | 6220 | 7385 |
| $F_1S_2$ | 5980 | 4100 | 5280 | 3790 | 4787 | 8310 | 5900 | 7510 | 6100 | 6955 |
| $F_1S_3$ | 5590 | 3850 | 3470 | 3600 | 4127 | 7650 | 6100 | 6020 | 5900 | 6417 |
| $F_2S_1$ | 8410 | 5720 | 7410 | 5200 | 6685 | 11000 | 8100 | 4980 | 7120 | 7800 |
| $F_2S_2$ | 7650 | 5010 | 6750 | 4600 | 6002 | 10520 | 7610 | 9350 | 6650 | 8532 |
| $F_2S_3$ | 7100 | 4700 | 4190 | 4300 | 5072 | 9950 | 7950 | 6400 | 6220 | 7630 |
| $F_3S_1$ | 7600 | 5020 | 6920 | 4590 | 6032 | 10620 | 7680 | 9720 | 6600 | 8655 |
| $F_3S_2$ | 7120 | 4430 | 3820 | 4400 | 4942 | 9800 | 6600 | 6300 | 4150 | 6712 |
| $F_3S_3$ | 6710 | 3980 | 3610 | 3630 | 4482 | 9300 | 6080 | 5950 | 5280 | 6652 |
| Mean | 6942 | 4567 | 5250 | 4235 | 5259 | 9563 | 6913 | 7158 | 6026 | 7415 |
| CD | VxDxFxS=161 | | | | | 198 | | | | |

| FS/VD | Wheat (2007-08) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Grain (Kg/ha) | | | | | Straw (Kg/ha) | | | | |
| | $V_1D_1$ | $V_1D_2$ | $V_2D_1$ | $V_2D_2$ | Mean | $V_1D_1$ | $V_1D_2$ | $V_2D_1$ | $V_2D_2$ | Mean |
| $F_1S_1$ | 4150 | 4180 | 3620 | 3800 | 3937 | 5780 | 6030 | 5325 | 5400 | 5634 |
| $F_1S_2$ | 4210 | 4290 | 3750 | 3720 | 3992 | 6100 | 6120 | 5380 | 5520 | 5780 |
| $F_1S_3$ | 4080 | 4200 | 3800 | 3700 | 3945 | 6250 | 6200 | 5200 | 5310 | 5740 |
| $F_2S_1$ | 5100 | 5310 | 4320 | 4450 | 4795 | 7300 | 7330 | 6480 | 6480 | 6897 |
| $F_2S_2$ | 5390 | 5650 | 4710 | 4800 | 5137 | 4620 | 7800 | 6610 | 6810 | 6460 |
| $F_2S_3$ | 5220 | 5329 | 4500 | 4600 | 4912 | 7350 | 7350 | 6370 | 6690 | 6940 |
| $F_3S_1$ | 5100 | 5200 | 4300 | 4510 | 4777 | 7100 | 7200 | 6390 | 6400 | 6772 |
| $F_3S_2$ | 5250 | 5310 | 4480 | 4590 | 4907 | 7610 | 7630 | 6480 | 6720 | 7110 |
| $F_3S_3$ | 5140 | 5520 | 4220 | 4430 | 4827 | 7390 | 7750 | 6040 | 6450 | 6907 |
| Mean | 4849 | 4999 | 4189 | 4289 | 5481 | 6611 | 7045 | 6030 | 6197 | 6471 |
| CD | VxDxFxS=138 | | | | | 162 | | | | |

best 5030 kg/ha and 5110 kg/ha during both years respectively (Table-2). This might be due to higher values of yield contributing characters which have positive correlation with grain yield. The results are accordance with the findings of Sinde *et al.* (2005) and Umed *etal.* (2009). Omission of K from the treatment ($F_3$) reduced the yield by 8.9% (392 kg/ha) in wheat on average basis. In case of seed rate, 125 kg/ha seed rate ($S_2$) yielded best of 4240 kg/ha during 2006-07 and 4343 kg/ha during 2007-08. Similar trend of results was noted for straw yield also (Table-3).

The interaction effect of variety and date of sowing revealed that PBW 343

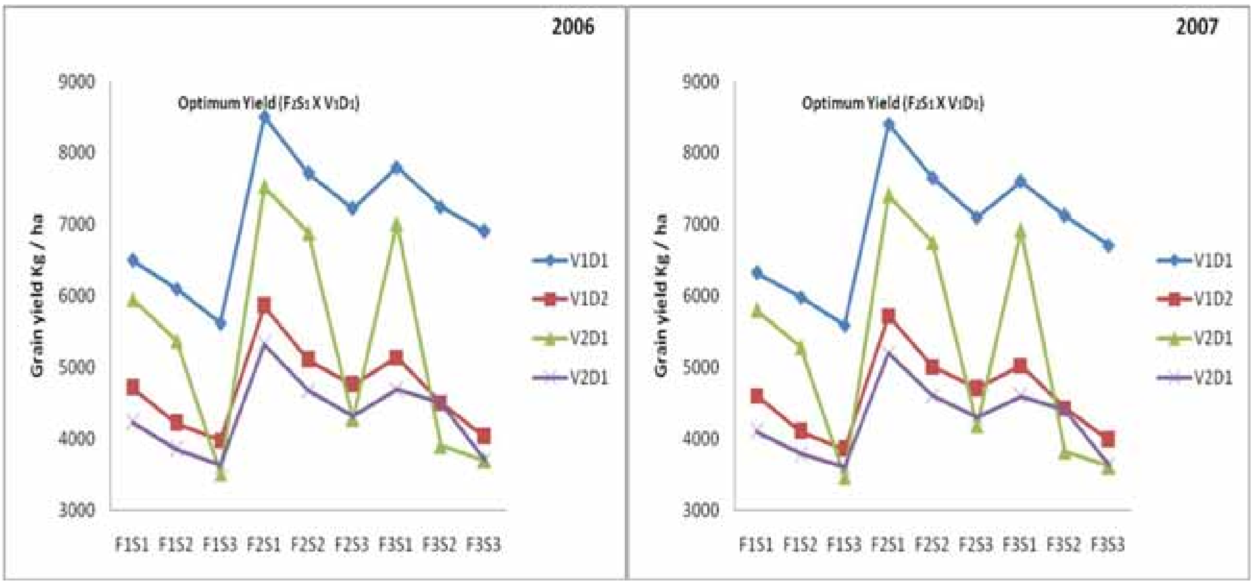


**Fig. 1. Response of Variety X seedling age X Fertilizer X Spacing on Rice grain yield during 2006-07**

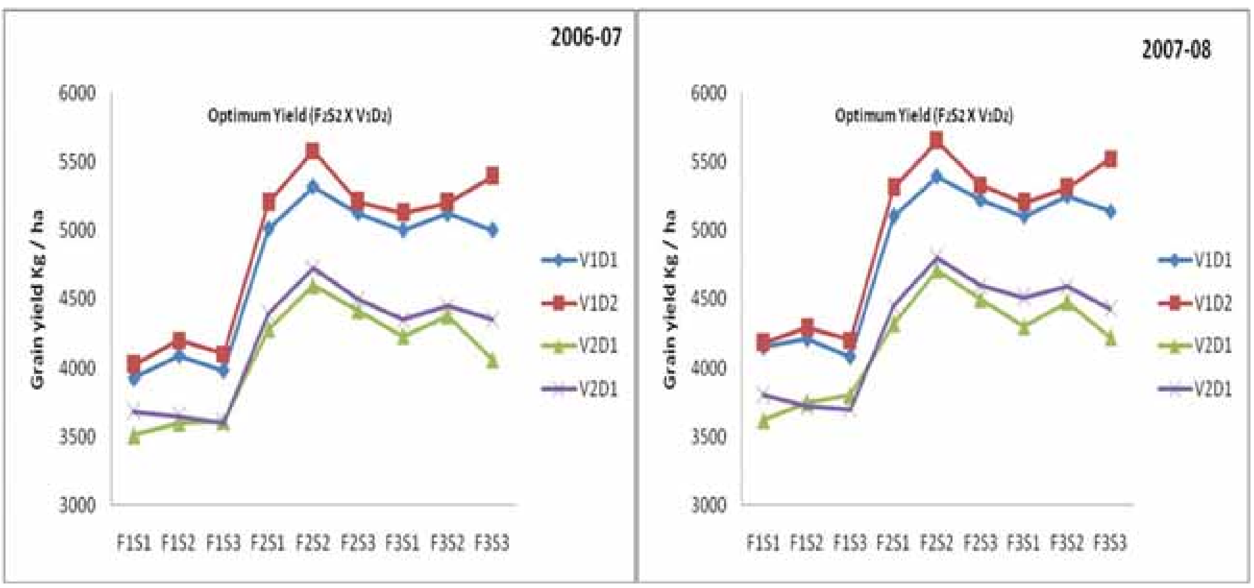


**Fig. 2. Response of Variety X date of sowing X Fertilizer X seed rate on Wheat grain yield during 2006-07 and 2007-08**

($V_1$) and December sowing ($D_2$) produced maximum seed yield to the level of 3955 kg/ha during 2006-07 and 4250 kg/ha during 2007-08.Similar trend was noted for straw yield too (Table-1). The combined effect of variety and different levels of fertilizer indicated that application of adequate balanced fertilizer such as $N_{150}$ + $P_2O_{5\ 60}$+ $K_2O_{\ 40}$+ $S_{40}$ + Zn $SO_4.7H_2O_{\ 25}$ kg/ha ($F_2$) with PBW-343 yielded best as 5810 kg/ha during first year and 5900 kg/ha during second year as compared to other treatments of variety x fertilizer (Table-2). The interaction of fertilizer levels and seed rate factors showed that combination of $N_{150}$ + $P_2O_{5\ 60}$+ $K_2O_{\ 40}$+ $S_{40}$ + Zn $SO_4.7H_2O_{\ 25}$ kg/ha ($F_2$) and 100 kg/ha ($S_1$) was significant than other combination of fertilizer levels and seed rate treatments and yielded 4580 kg/ha and 4650 kg/ha during both years, respectively (Table-3). Combination of $V_1$ x $S_2$ (PBW 343 x 125 kg $ha^{-1}$ ) treatment yielded maximum wheat 4890 kg $ha^{-1}$ and 4950 kg $ha^{-1}$ during 2006-07 and 2007-08 respectively (Table-5). Date of sowing interact with different level of seed rate revealed that 125 kg/ha seed of wheat sown on December produced maximum yield of 4810 kg/ha during 2006-07 and 4900 kg/ha during 2007-08 (Table-6).Wheat variety PBW-343 sown on December at the seed rate of 125 kg/ha was yielded maximum as 5510 $kgha^{-1}$ during 2006-07 and 5600 kg $ha^{-1}$ during 2007-08 (Table-7). Interaction of $V_1$ x $F_2$ x $S_2$ (PBW 343 x adequate balanced fertilizer x 125 kg/ha seed rate) showed maximum wheat yield of 5500 kg/ha and 5600 kg/ha during both years, respectively (Table-8). The combination of $D_2$ x $F_2$ x $S_2$ was best (5800 kg $ha^{-1}$ and 5920 kg $ha^{-1}$) during both years, respectively (Table-9) & Fig.-2. Our results are similar to Akhtar *et al.* (2006) and Muhammad *et al.* (2009).

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# RESPONSE OF GROWTH REGULATORS AND INORGANIC FERTILIZERS ON GROWTH, FLOWERING AND YIELD OF CHRYSANTHEMUM (*DENDRANTHEMA GRANDIFLORA* RAMAT.) CV. BIRBAL SAHNI

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## ABSTRACT

A field trial was conducted to investigate the response of vegetative growth, flowering and yield in chrysanthemum cv. Birbal sahni during 2007-08. To study the optimum concentrations of gibberellic acid at three levels 50 ppm, 100 ppm and 150 ppm, cycocel with three levels 1000 ppm, 5000 ppm and 10000 ppm and also three levels of inorganic fertilizers $N_1$ (100 kg $N_2$ + 60 kg $P_2O_5$ + 40 kg $K_2O$/ha), $N_2$ (150 kg $N_2$ +120 kg $P_2O_5$ + 80 kg $K_2O$/ha) and $N_3$(200 kg $N_2$ + 180 kg $P_2O_5$ + 120 kg $K_2O$/ha) appreciably improved the growth, flowering and flower yield attributes of chrysanthemum. Maximum plant height (cm), plant spread (cm), diameter of main stem (cm), number of branches/plant, days taken to flowering, flower size (cm), number of flower/plant, flower weight/plant (g) and shelf life of flower (days) were recorded beneficially at 150 ppm concentration of GA3 and 5000 ppm concentration of CCC. However, the inorganic fertilizers significantly affected the above characters of chrysanthemum.

**Key word:** Chrysanthemum, Growth Regulators, Inorganic Fertilizers.

## INTRODUCTION

The commercial importance of flowers has been realized throughout the world and today, floriculture has developed into an intensive form of agriculture. In India the leading flowers growing states are Karnataka, Tamil Nadu, Andhra Pradesh, West Bengal, Maharashtra and Uttar Pradesh. Chrysanthemum (*Dendranthema grandiflora* Ramat.) is one of the most important commercial flower crops in India and abroad. Chrysanthemum is now becoming popular day by day due to its unparallel diversity in shape, size, color, growth habit and post-harvest life. Chrysanthemum is commonly known as guldaudi, chandramallika, queen of the east, glory of the east and grown for as well as cut flowers and loose flower purpose in addition to pot culture. It commercially propagated through root suckers and terminal stem cuttings. The cultivar Birbal Sahni is a pompon spray type, white flower cultivar which released from National Botanical Research Institute, Lucknow. It cultivar may be effected by several agro-techniques such as growth regulators, nutrients, pinching, staking, hoeing, irrigation etc. It is desired to increase the number of flowers and yield in addition the explore possibility to derive early bloom with the help of growth regulators treatment, so as to raise the market value of the culture. The use of growth regulators also enables removal or circumvention of many of the barriers imposed by heredity and environment. Normal plant growth and development is controlled by endogenous plants hormones, the chemicals produced by plant itself. Information on physiology and metabolism is neither extensive nor comprehensive and the processes which go on within the plant are very difficult to test. However, some of the studies conduct with regards to occurrence of growth substances suggests that the gibberellins are involved in the developmental physiology of ornamental plants. In order to improve the growth and flower production with the doses of inorganic fertilizers, the results of work on cultivar Birbal Sahni was initiated here.

## MATERIALS AND METHODS

The field experiment was conducted at Horticulture Research Farm, C. C. S. University, Meerut in a factorial randomized block design. The experiment was consisted with three replication and 28 treatment combinations. Three concentration of $GA_3$ with $G_1$ (50 ppm), $G_2$ (100 ppm) and $G_3$ (150 ppm), three concentrations of CCC with $C_1$ (1000 ppm), $C_2$ (5000 ppm) and $C_3$ (10000 ppm) was sprayed 30 and 45 days of transplanting through hand atomizer in the cool morning hours when dew dry up. The application of inorganic fertilizers at three levels viz. $N_1$ (100 kg $N_2$ + 60 kg $P_2O_5$ + 40 kg $K_2O$/ha), $N_2$(150 kg $N_2$ +120 kg $P_2O_5$ + 80 kg $K_2O$/ha) and $N_3$(200 kg $N_2$ + 180 kg $P_2O_5$ + 120 kg $K_2O$/ha) were used. The entire quantities of farm yard manure, phosphorus, potassium and half amount of total quantity of nitrogen was applied into two split doses at 30 days interval. Nitrogen was applied in the form of urea, phosphorus in the form of single super phosphate and potassium in the form of muriate of potash. Intercultural operations like weeding, staking, pinching, irrigation and plant protection measures were done as and when necessary. The observation of different parameters as mentioned Table 1 and statistically analyzed data recorded on plant height (cm), plant spread (cm), diameter of main stem (cm), number of branches/plant, days taken to flowering, flower size (cm), number of flower/plant, flower weight/plant (g) and shelf life of flower (days).

## RESULT AND DISCUSSION

### Vegetative Growth Attributes

The data depicted in the Table 1 indicated that increased application the plant height, plant spread, diameter of main stem and number of branches/ plant. The importance of growth regulators as gibberellic acid and cycocel in promoting vegetative growth has been emphasized (Nagarjuna *et al.*1988 and Singh *et al.* 1999). Like $N_2$, $P_2O_5$ and $K_2O$ also improved the vegetative growth of chrysanthemum plant. The maximum plant height increased with the increase in concentration of $GA_3$ 50 to 150 and all the treatments of $GA_3$ significantly increased the plant height over control and other treatment of CCC and inorganic fertilizers. The differences among various concentration of $GA_3$ were also found significant. However, maximum plant height (58.60 cm) was recorded in plant sprayed with 150 ppm concentration of $GA_3$. Highest reduction in plant height (31.61 cm) was recorded in the plant sprayed with 5000 ppm concentration of CCC while, inorganic fertilizers increased plant height with increasing the amount of NPK. The maximum plant height (48.19 cm) were observed under the treatment of $N_3$ (200 kg $N_2$ + 180 kg $P_2O_5$ + 120 kg $K_2O$/ha) over control. The increased in plant height with the application of $GA_3$ can be attributed to longer internodes and increased number of internodes which might be due to enhanced cell division and cell elongation in sub apical meristem, increased photosynthesis and

**Table 1. Response of growth regulators and inorganic fertilizers on growth, flowering and yield of chrysanthemum cv. Birbal Sahni.**

| Treatments | Plant Height (cm) | Plant Spread (cm) | Diameter of main Stem (cm) | No. of Branches /Plant | Days Taken to Flowering | Flower Size (cm) | No. of Flowers /Plant | Flower Weight /Plant (g) | Shalf Life (days) |
|---|---|---|---|---|---|---|---|---|---|
| Control | 41.52 | 19.22 | 1.55 | 11.18 | 98.72 | 2.78 | 48.17 | 68.46 | 13.82 |
| $GA_3$ (ppm) | | | | | | | | | |
| $G_1$(50) | 51.20 | 25.78 | 1.68 | 12.82 | 92.29 | 3.67 | 61.29 | 82.36 | |
| $G_2$ (100) | 54.79 | 29.12 | 1.85 | 15.73 | 90.23 | 3.99 | 66.84 | 87.44 | 15.24 |
| $G_3$ (150) | 58.60 | 31.79 | 1.94 | 17.22 | 93.18 | 4.29 | 69.53 | 92.06 | |
| CCC (ppm) | | | | | | | | | 15.87 |
| $C_1$ (1000) | 34.13 | 20.54 | 1.86 | 13.61 | 100.72 | 3.22 | 55.56 | 75.34 | |
| $C_2$ (5000) | 31.61 | 22.69 | 1.99 | 15.14 | 104.59 | 3.89 | 60.10 | 77.32 | 18.29 |
| $C_3$ (10,000) | 33.93 | 21.65 | 1.87 | 12.39 | 102.68 | 3.62 | 57.43 | 76.34 | |
| NPK (kg/ha) | | | | | | | | | |
| $N_1$ | 44.24 | 23.15 | 1.67 | 11.06 | 97.16 | 2.99 | 56.65 | 78.41 | 15.95 |
| $N_2$ | 46.52 | 24.43 | 1.69 | 14.87 | 95.57 | 3.20 | 60.18 | 81.36 | 18.63 |
| $N_3$ | 48.19 | 25.82 | 1.72 | 16.30 | 94.67 | 3.49 | 65.26 | 84.16 | 16.73 |
| | | | | | | | | | 15.61 |
| | | | | | | | | | 17.64 |
| | | | | | | | | | 16.35 |
| SEm± | 0.44 | 0.48 | 0.03 | 0.68 | 0.58 | 0.28 | 2.69 | 0.76 | 0.54 |
| C.D. at 5 % | 1.31 | 1.43 | 0.09 | 2.04 | 1.73 | 0.86 | 1.40 | 2.29 | 1.61 |

respiration along with enhanced $CO_2$ fixation which reported by (Korish *et al.* 1989). All the $GA_3$, CCC and NPK treatments affected the plant spread significantly over control. The maximum plant spread (30.79 cm)was recorded with treatment $GA_3$ 150 ppm comparison to control (19.22 cm) and (22.69 cm) with the concentration of CCC 5000 ppm. The increasing the maximum plant spread (25.82 cm) with the increased quantity of inorganic fertilizers. The result of the study indicated that $GA_3$ at 150 ppm concentration considerably increased the diameter of main stem (1.94 cm)while, maximum diameter of main stem (1.99 cm) was recorded plant sprayed with 5000 ppm concentration of CCC to over control and all concentration of $GA_3$ and NPK. Talukdar *et al.* (1994) also reported the beneficial effect of $GA_3$ and CCC. The cultivar Birbal Sahni responded well to the spraying of $GA_3$, CCC and application of NPK showed significant maximum number of branches/plant (17.22) compare to CCC and NPK concentration. It was reported to induce the more number of branches in chrysanthemum finding by Nagarajuna, *et al.* (1988).

**Flowering Attributes**

The growth regulators treatments of 50 ppm, 100 ppm and 150 ppm $GA_3$ significantly reduced the duration for days taken to flowering with duration of (92.29), (90.23) and (93.18) days respectively compared to (98.72) days as was observed by control and (104.59) days maximum recorded with the treatment of CCC, 5000 ppm. It might be due to the fact that gibberellins induce the flowering in long day plants with specific day length requirement. Similar results were also obtained by Mohariya *et al.* (2003). Further the cycocel treatments delayed flowering but extended the periodicity of flowering as compared to untreated plants. Similar findings were observed by Seeta and Sehgal (1994) in chrysanthemum.

However, $N_1$, $N_2$ and $N_3$ significantly reduced the duration of flowering which showing (97.16), (95.57) and (94.67) days then over control. Similar earliness in flowering at lower levels of $GA_3$ was also reported by Dutta and Kher (1993). The maximum flower size recorded (4.29 cm) with 150 ppm concentration of $GA_3$ over control (2.78 cm) and other concentrations of $GA_3$. The enhancement in flower size with $GA_3$ may have been due to a close parallelism between vegetative growth and flowering and it is possible that promontory effect of $GA_3$ on vegetative growth associated with efficient mobilization capacity. Similar finding were observed by Moond *et al.* (2006). The concentration of CCC, 5000 ppm recorded maximum flower size (3.89 cm) over control and all respective concentration of inorganic fertilizers. Similar findings were observed by Gautam and Dashora (2006).

**Flower Yield Attributes**

Increasing the number of flowers without affecting the quality using growth regulators is a desirable trait in case of spray cultivar. The treatment of $GA_3$ 150 ppm and CCC 5000 ppm increasing the number of flowers (69.53) and (60.10) respectively over control (48.17) and other respective concentrations of growth regulators ( increase by (19.36) and (11.93) number of flowers then control). The treatment of NPK significantly increasing the number of flowers compare to control. Increase number of flowers with the treatment of $GA_3$ concentrations in the present investigation is in agreement with the findings of Nagarjuna *et al.* (1988) and Farooqi *et al.* (1999). Chrysanthemum variety Birbal Sahni produced more flower weight/plant (g) and shelf life (days) with the application of growth regulators and NPK. The treatments were significantly superior over control. The highest flower weight/plant (92.06 g) was recorded at 150 ppm concentration of $GA_3$ compare to (77.32 g) with 5000 ppm concentration of CCC, (84.16 g) with the treatment of NPK @ 200 kg $N_2$ + 180 kg $P_2O_5$ + 120 kg $K_2O$/ha and over control (68.46 g). The increase flower weight/ plant (g) with $GA_3$ concentration observed in the present investigation is in agreement with the findings of Beniwal *et al.* (2005) and Lodhi and Pathak (1991). The weight of flowers increased due to in addition rate of photosynthesis is also accelerated by earlier formation of flower buds with cycocel, which provides the sink for accepting the surplus assimilates and avoids the accumulation of photosynthetic. Mohariya *et al.* (2003) was recorded the same view in chrysanthemum, who found that the use of CCC for improving the flower weight in chrysanthemum. The data showed that the shelf life of flowers increase with the increase in concentration of $GA_3$ from 50 to 150 ppm and (17.64) days observed with the application of NPK treatment $N_2$ (150 kg $N_2$ +120 kg $P_2O_5$ + 80 kg $K_2O$/ha) over control (13.82) days. The maximum shelf life (18.63) days observed with the treatment of 5000 ppm concentration of CCC over all respective treatments of $GA_3$ and NPK. The improvement in flower shelf life might have been due to the increase activity of amylase enzyme by $GA_3$, which hydrolyzed the extensive starch reserves and released the reducing sugar. Reducing sugars being osmotic ally active cause an influence of water, resulting in increased shelf life of flowers. The findings are in accordance with the findings of Joshi *et al.* (2008).

## CONCLUSION

The present result revealed that the 150 ppm concentration of $GA_3$ and 5000 ppm concentration of CCC was found beneficial for plant height, plant spread, diameter of main stem, number of branches, number of flowers per plant, flower size, flower weight per plant and shelf life of flowers, while $GA_3$ at 100 ppm show the better effect in respect to day taken to flowering and CCC 5000 ppm maximum increased the shelf life of flowers. The application of inorganic fertilizers @ 200 kg $N_2$ + 180 kg $P_2O_5$ + 120 kg $K_2O$ /ha was found better for plant height, plant spread, diameter of main stem, number of branches, days taken to flowering, number of flowers per plant, flower size, flower weight per plant (g), while inorganic fertilizers @ 150 kg $N_2$ + 120 kg $P_2O_5$ + 80 kg $K_2O$ /ha was found beneficial for maximum shelf life of flowers in chrysanthemum cv. Birbal Sahni.

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# DIVERSIFICATION OF PEARL MILLET (*PENNISETUM GLAUCUM*) -WHEAT (*TRITICUM AESTIVUM*) CROPPING SYSTEM IN SEMI ARID RAJASTHAN

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## Abstract

The field experiment was conducted at farmer's field in Dausa district of Rajasthan during 2005-06 to 2006-07 in farmer participatory research mode under Rajasthan Water Sector Restructuring Project (RWSRP) at three locations. The wheat equivalent yield was highest (114.54 q/ha) under groundnut-onion crop sequence followed by cotton-vegetable pea crop sequence (64.54 q/ha). Production efficiency was also higher i.e.40.91 kg/ha/day in groundnut-onion crop sequence. Whereas land uses efficiency was maximum (87.67%) in cotton-vegetable pea crop sequence followed by groundnut-onion crop sequence (76.71%). Among six selected crop sequence, significantly highest net return was observed in groundnut-onion crop sequence during both the years at all the locations. The mean net returns over the years and the locations was maximum (Rs 60632/ha) in groundnut-onion crop sequence followed by the returns of Rs37544/ha in cotton-vegetable pea crop sequence. However, mean water requirement was also highest i.e.1768mm in this rotation. Cotton-vegetable pea was the next better crop sequence in order of significance with having almost same water requirement to the existing crop rotation (pearl millet-wheat).

**Key words:** Cropping systems, Diversification, Production potential, Economics, Soil fertility status, Nutrient uptake

Pearl millet-wheat is main cropping system in the area and is continuously followed by the farmers of the area. Continuously following the same system has adverse effect on soil conditions and ultimately reducing the productivity of the system (Nambiar and Abrol, 1989; Kumar and Yadav, 1993). Diversifying the system with other system has been found effectively minimize insect, pest and disease infestation while inclusion of legumes and green manures improves the fertility of the soil. This enables the best use of available resources and improves returns/unit of land and water. Inclusion of pulses, oilseed and vegetables in the system is more beneficial than cereal after cereals (Kumpawat, 2001; Raskar and Bhoi, 2001). Thus diversification of the existing production system is needed in the area. Looking to these facts, the present experiment was conducted to find out the possibilities of diversification in traditional pearl millet-wheat cropping system in view of sustainability, soil health and maximizing economic returns of the farmers in the area.

## Materials and Methods

The field trial was conducted at farmer's field in Dausa district of Rajasthan during 2005-06 to 2006-07 in farmer participatory research mode under Rajasthan Water Sector Restructuring Project (RWSRP) at three locations. Six cropping systems viz. Pearl millet-Wheat, Groundnut-Onion, Guar-Ajwain, Cotton-Vegetable Pea, Maize

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(cob)-Fenugreek and Moong bean-Mustard were evaluated for their production potential and economics in randomized block design with four replications on fixed site. The crops were raised under irrigated condition at all the locations during both years with recommended package of practices. Nitrogen, phosphorus and potassium were supplied through urea, DAP and MOP. Total rainfall received was 558 mm and 424 mm during 2005-06 and 2006-07, respectively. The prevailing market price of different commodities was used to work out the economics of different systems. Wheat grain equivalent yield was calculated by multiplying yield with price of produce and divided by price of wheat. The land use efficiency was worked out by dividing total duration of crops in individual cropping system by 365(days) and production efficiency was obtained by dividing total production in a system by total duration of crops in that system. Changes in soil fertility status were studied after two complete cycle of experimentation by analyzing the soil samples at initial and final stage.

## Results and Discussion

### Yield

The data on mean grain and straw / stover yields of various location and mean wheat grain equivalent yield presented in table 1 indicated that wheat grain equivalent yield was maximum (114.54 q/ha) in groundnut-onion crop sequence followed by cotton-vegetable pea (64.54 q/ ha). Production efficiency was also higher i.e.40.91 kg/ha/day in groundnut-onion crop sequence. Whereas, Land uses efficiency was maximum (87.67%) in cotton-vegetable pea crop sequence followed by groundnut-onion crop sequence (76.71%). The highest irrigation water requirement of 1768 mm/ ha/year was also recorded in groundnut-onion crop sequence followed by cotton-vegetable pea (1018 mm/ha/year) which was almost same water requirement as in existing pearl millet-wheat cropping system (918mm/ha/year).

### Economic returns

The data (table 2) indicated that among six selected crop sequences, significantly highest net return was observed in groundnut-onion crop sequence at all the locations during both the years. Inclusion of onion in the system increased the cultivation cost as it required heavy fertilization and labour. However, mean net returns were also highest in this system because of higher value of produce. Groundnut- onion cropping system fetched mean net returns of Rs 60632/ha/year and proved to be the most remunerative cropping system. Cotton- vegetable pea was the next better cropping system in order of significance with net returns of Rs.37544/ha/year as compared with existing pearl millet-wheat cropping system (Rs32755/ha/year). These results are close conformity with the results of Sharma *et al.* (2004).

### Nutrient uptake

The mean data (table 3) on total uptake of N P and K by various crop sequences at various locations over the years indicated that maximum uptake of N (208.3kg/ha) was recorded in ground nut–wheat crop sequence followed by cotton-vegetable pea crop sequence (173.8kg/ha). Highest P uptake of 52.4 kg/ha was recorded under pearl millet-wheat crop sequence followed by maize-fenugreek crop sequence (37.8 kg/ha)

**Table 1**. **Yield, wheat equivalent yield, land use efficiency, production efficiency, water requirement and water use efficiency of different crop sequences (mean over the locations and years)**

| Crop Sequence | Mean Yield of two years(q/ha) | | | | | | Mean Yield (q/ha) over the locaation | | Wheat equivalent yield (q/ha) | Land use efficiency (%) | Production efficiency (kg/ha day) | Water Requirement (mm) of sequence | WUE (kg/ha mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Location I | | Location II | | Location III | | | | | | | | |
| | Kharif | Rabi | Kharif | Rabi | Kharif | Rabi | Kharif | Rabi | | | | | |
| Pearl millet-Wheat | 24.63 (46.38) | 22.13 (47.72) | 22.54 (44.72) | 20.56 (40.72) | 24.16 (44.72) | 36.19 (49.98) | 23.78 (45.27) | 26.29 (46.14) | 39.34 | 57.53 | 18.73 | 918 | 12.15 |
| Groundnut-Onion | 24.09 (-) | 205.62 (-) | 19.09 (-) | 176.75 (-) | 17.38 (-) | 231.67 (-) | 20.18 (-) | 204.68 (-) | 114.54 | 76.71 | 40.91 | 1768 | 21.81 |
| Guar-Ajwain | 8.72 (18.48) | 2.34 (-) | 6.83 (15.97) | 5.84 (-) | 7.68 (17.84) | 6.09 (-) | 7.74 (17.43) | 4.76 (-) | 52.94 | 67.12 | 21.61 | 868 | 3.09 |
| Cotton-Vegetable Pea | 17.70 (-) | 44.99 (46.51) | 17.27 (-) | 59.10 (37.77) | 10.86 (-) | 89.63 (50.10) | 15.28 (-) | 64.57 (44.79) | 64.54 | 87.67 | 20.17 | 1018 | 24.40 |
| Maize(cob)-Fenugreek | 72.26 (87.50) | 6.87 (21.27) | 52.24 (60.00) | 9.47 (24.49) | 52.52 (59.12) | 15.35 (19.42) | 59.01 (68.87) | 10.56 (21.73) | 32.98 | 69.04 | 13.09 | 968 | 13.81 |
| Mung bean-Mustard | 5.40 (14.07) | 9.08 (24.32) | 4.50 (11.44) | 7.64 (22.34) | 6.44 (15.13) | 13.03 (28.13) | 5.45 (13.55) | 9.92 (25.13) | 32.29 | 52.88 | 16.73 | 768 | 6.47 |

Figures in parentheses are straw/ stover yield

**Table 2. Net Return (Rs/ha) by crops under different crop Sequences**

| Crop Sequence | Net Return (Rs/ha) by crops | | | | | | | | | Mean Net Return Over the Locat-ions |
|---|---|---|---|---|---|---|---|---|---|---|
| | Location I | | | Location II | | | Location III | | | |
| | 2005-06 | 2006-07 | Mean | 2005-06 | 2006-07 | Mean | 2005-06 | 2006-07 | Mean | |
| Pearl millet-Wheat | 37420 | 21062 | 29241 | 28961 | 22118 | 25540 | 37377 | 49591 | 43484 | 32755 |
| Groundnut-Onion | 67423 | 66763 | 67093 | 52598 | 45513 | 49056 | 62623 | 68873 | 65748 | 60632 |
| Guar-Ajwain | 9669 | 10245 | 9957 | 39939 | 373 | 20156 | 24699 | 20863 | 22781 | 17631 |
| Cotton-Vegetable Pea | 38624 | 26473 | 32549 | 41912 | 34864 | 38388 | 57043 | 26347 | 41695 | 37544 |
| Maize(cob)-Fenugreek | 24257 | 23155 | 23706 | 10635 | 22065 | 16350 | 12604 | 37999 | 25302 | 21786 |
| Mung bean-Mustard | 21102 | 9264 | 15183 | 15539 | 508 | 8024 | 25871 | 17570 | 21721 | 14976 |
| C D (P=0.05) | 5653 | 5141 | - | 4846 | 4970 | - | 3899 | 5148 | - | - |

**Table 3. Total nutrient uptake (kg/ha) by crops under different crop Sequences (mean of two years)**

| Crop Sequence | Location I | | | Location II | | | Location III | | | Mean uptake overthe Locations | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | P | K | N | P | K | N | P | K | N | P | K |
| Pearl millet-Wheat | 143.4 | 55.2 | 181.0 | 112.7 | 46.3 | 142.9 | 140.8 | 55.6 | 171.9 | 132.3 | 52.4 | 165.3 |
| Groundnut-Onion | 264.4 | 35.9 | 150.3 | 175.2 | 31.9 | 139.1 | 185.6 | 34.2 | 150.7 | 208.4 | 34.0 | 146.7 |
| Guar-Ajwain | 108.8 | 13.6 | 78.4 | 80.8 | 15.2 | 94.2 | 86.9 | 14.9 | 88.4 | 92.2 | 14.6 | 87.0 |
| Cotton-Vegetable Pea | 187.6 | 45.2 | 191.5 | 169.5 | 34.4 | 194.5 | 164.3 | 31.7 | 190.9 | 173.8 | 37.1 | 192.3 |
| Maize(cob)-Fenugreek | 78.5 | 33.7 | 142.9 | 88.9 | 45.6 | 125.9 | 97.1 | 34.2 | 117.3 | 88.2 | 37.8 | 128.7 |
| Mung bean-Mustard | 97.4 | 17.1 | 66.8 | 67.5 | 17.8 | 50.2 | 102.5 | 18.8 | 73.9 | 89.1 | 17.9 | 63.6 |

and cotton-vegetable pea (37.1 kg/ha). Whereas, maximum K uptake (192.3 kg/ha) was recorded in cotton-vegetable pea crop sequence followed by pearl millet-wheat crop sequence (165.3 kg/ha).

## Nutrient status of the soil

The initial and final nutrient status of soil of different crop rotations of three locations of farmer's field (table 4) showed that there was depletion of nitrogen and potash from the soil at location I in pearl millet- wheat and maize (cob/seed)-fenugreek crop sequences after completion of sequence for two years. There was no depletion of N, $P_2O_5$ and $K_2O$ from soil in groundnut-onion and mungbean-mustard crop sequence, however there was depletion of potash from soil in cotton-vegetable pea and maize (cob/seed)-fenugreek crop sequences. There was no depletion of phosphorus from soil in all the crop sequences after taking crop for two years. At location II, there was no depletion of N and $P_2O_5$ from soil in all the crop sequences whereas, there was

**Table 4. Changes in soil fertility parameters after two crop cycle as influenced by different cropping systems**

| Location | Crop sequences | Available N (kg/ha) | Available $P_2O_5$ (kg/ha) | Available $K_2O$ (kg/ha) |
|---|---|---|---|---|
| Location I | $T_1$ = Pearl millet-Wheat | 206.38 | 34.00 | 266 |
| | $T_2$ = Groundnut-Onion | 216.28 | 34.70 | 282 |
| | $T_3$ = Guar-Ajwain | 219.52 | 37.29 | 272 |
| | $T_4$ = Cotton-Vegetable Pea | 235.20 | 39.79 | 262 |
| | $T_5$ = Maize(cob/seed)-Fenugreek | 210.11 | 37.93 | 260 |
| | $T_6$ = Mung bean-Mustard | 225.79 | 39.79 | 276 |
| | Initial soil test values | 216.28 | 28.60 | 272.80 |
| Location II | $T_1$ = Pearl millet-Wheat | 160.11 | 40.36 | 170 |
| | $T_2$ = Groundnut-Onion | 151.27 | 38.50 | 188 |
| | $T_3$ = Guar-Ajwain | 159.52 | 40.08 | 172 |
| | $T_4$ = Cotton-Vegetable Pea | 153.25 | 40.67 | 178 |
| | $T_5$ = Maize(cob/seed)-Fenugreek | 150.11 | 38.29 | 184 |
| | $T_6$ = Mung bean-Mustard | 153.84 | 36.87 | 176 |
| | Initial soil test values | 132.05 | 34.30 | 176.00 |
| Location III | $T_1$ = Pearl millet-Wheat | 176.98 | 41.29 | 186 |
| | $T_2$ = Groundnut-Onion | 180.11 | 47.50 | 196 |
| | $T_3$ = Guar-Ajwain | 173.84 | 44.15 | 184 |
| | $T_4$ = Cotton-Vegetable Pea | 195.79 | 46.15 | 178 |
| | $T_5$ = Maize(cob/seed)-Fenugreek | 180.11 | 47.36 | 176 |
| | $T_6$ = Mung bean-Mustard | 186.38 | 47.36 | 184 |
| | Initial soil test values | 169.34 | 43.47 | 176.00 |

depletion of $K_2O$ in the soil in pearl millet- wheat crop sequence. At location III, it is inferred from the data that there was no depletion of available N, $P_2O_5$ and $K_2O$ in the soil after taking crop for two years i.e. 2005-06 and 2006-07 except $P_2O_5$ in pearl millet- wheat crop sequence where slight decrease in available $P_2O_5$ was observed. Similar results were also observed by Verma and Mudgal (1983) in maize-wheat cropping system.

Thus, it may be concluded that farmers with adequate resources including water have ample scope for crop diversification adopting groundnut-onion and cotton-vegetable pea copping systems as alternatives, replacing conventional system of pearl millet-wheat for higher productivity and profitability and for maintaining soil health.

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# RESISTANCE IN RAPESEED GERMPLASM AGAINST THE ALTERNARIA LEAF SPOT CAUSED BY *ALTERNARIA BRASSICA* (BERK) SACC.

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## Abstract

Indian mustard [*Brassica juncea* (L.) Czeen and Coss] is one of the major oilseed crops cultivated in India and all over the world. In India, Uttar Pradesh is the second largest producer of rapeseed mustard after Rajasthan, having an area of 1.2 million hectare with the production of 0.7 million tones. The average productivity of mustard in India is about 9.68 q/ha which is much below than international standard (13q/ha.). The main reasons of low production are diseases. The crop is affected by more than twenty fungal, bacterial, viral, mycoplasma, phanerogamic parasites and physiological diseases. Among them, the leaf spot disease caused by *Alternaria brassica* (Berk) Sacc. is one of the most widespread and destructive disease of mustard under natural condition. The disease was first reported by Dey (1945) in Uttar Pradesh which caused severe losses in yield. The development of resistant variety against Alternaria blight provides an easy, cheaper and effective means of disease control. Therefore, the present study was undertaken to find out the source of resistant against this disease.

Studies on screening of available genotype were carried out with artificial inoculation under field condition. In order to promote a severe natural epidemic of disease, the sowing of crop was done about four weeks later than the normal planting (1st week of October) at Experimental Research Farm, C. S. Azad University of Agriculture & Technology, Kanpur during 2002-03.The experiment was conducted at Randomized Block Design with row to row distance is 30 cm and plant to plant 10 cm. The recommended dose of fertilizer was applied for raising a good crop. To maintain high humidity level microclimate of the field, time to time irrigations were applied to facilitate development of disease.

The inoculum of *A. brassica* was prepared by mycelial mat collected from 7 days old culture in sterilized water. The suspension containing conidia and mycelial bit was churned in a waring blender for 3 minutes and strained with cheesecloth. The test inoculums containing approximately $10^3$-$10^5$ conidia/ml was sprayed on plant at branching and siliquae formation stage. After 15 days of inoculation disease observations were recorded. 50 leaves of mustered plants were randomly selected and number of lesion per leaf for each treatment was countered. Disease was recorded using a score chart consisting of five (0, 1, 2, 3, 4) different grades of infection, prepared on the basis of the percentage of infected area over total areas of the infected leaves. The leaves without sign of infection received score of 0.Similarly, leaves with 1-5, 6-20, 21-30 and above 40% area covered with lesion received a score of 1, 2, 3, 4, respectively (Husain & Thakur, 1963). The percent diseases incidence (PDI) was calculated by the following formula:-

$$\text{Disease severity (PDI)} = \frac{\Sigma \text{ Class rating} \times \text{Class frequency}}{\text{Total no. of leaves} \times \text{maximum class rating}} \times 100$$

On the basis of calculated PDI data, the variety was screened as Immune (no infection), resistant (up to 5% infection), moderately resistant (upto 10%), moderately susceptible (upto 20%), Susceptible (upto 30%) & highly susceptible (up to 40% infection).

It was evident from the Table – 1, showed that out of 37 genotypes, non of them was found free or resistant against the disease under natural condition. Four genotypes namely, Rohini, PBR-97, HC-9605 and BCRS-4, were found moderately resistant (MR), remaining 12, 11 and 10 genotype were showed moderately susceptible, susceptible, and highly susceptible reaction, respectively.

With regard to 27 genotypes tested under artificial condition, none of them was found free and resistant against the disease. Only three genotypes namely EC-399296, PBR-91 and EC-338997 were found moderately resistant against the pathogen. Remaining 7 were showed moderately susceptible, 14 susceptible and 3 highly susceptible reaction. None of variety was found immune in both natural and artificial condition. Khan *et al.* (1991) reported that 100 accession of sarson were evaluated as moderately resistant,16 moderately susceptible, 53 susceptible and 26 highly susceptible against Alternaria blight but no one was found resistance under field condition. Vishwanath and Kolte (1999) also reported that out of 350 germplasm lines of *Brassica* spp., 22 gremplasm lines showed less than 1% infection in a 0-5 rating scale indicating a high degree of resistant against *A. brassicae*.

The germplasm has been found to

**Table 1. Reaction of Mustard genotypes against Alternaria blight**

| S. No. | Reaction | Grade | Genotypes Natural Condition | Genotypes Artificial condition |
|---|---|---|---|---|
| 1 | Free | 0 | — | - |
| 2 | Resistant (R) | 1 | — | - |
| 3 | Moderately Resistant (MR) | 2 | Rohini, PBR-97, HC-9605, BRCS-4 | EC-399296,PBR-91,EC-338997 |
| 4 | Moderately susceptible (MS) | 3 | Kranti, RL-1359, RK-2001, PCR-10, CS-52, RGNC, Kiran, JTC-18, BCRS-4, HNS-9605, RN-505, TKG-181. | Kranti, PBR-2002, EC-339000, DLN-75,RN-510,Varuna and JYM-10 |
| 5 | Susceptible (S) | 4 | RN-510, Varuna, Bio-902, PCR-7, RH-819, SEJ-2, PBC-9902, HNS-99(00)3, DCSC 03, NPJ-87, BIO 9E36-99. | PBR-181, RN-505, PHR-2, RGN-36, NPJ-91, PBC-9921, PBN-2001, PUR-214, JMM-991, RL-99-27, RN-510, HUM-9907, PR-9801 and TM-20 |
| 6 | Highly Susceptible (HS) | 5 | ND45-4504, Rajendra Sarson, NDYS-2, GSC-861-212, GSC-865-2, GSX-3A, HNS-9601, NUDB-42, TKG-24, RTM-314 | MDYR-2029, RSR-48, JGM-9005 |

resistant in the present investigation can be utilized in resistance breeding programme against leaf spot pathogen.

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# RESPONSE OF WHEAT VARIETIES TO SOWING TIMES UNDER AGRO-CLIMATIC CONDITIONS OF BUNDELKHAND

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ABSTRACT

Experiments were laid out under three sowing dates in Parwa and Kabar soils involving recommended varieties of wheat during winter of 2006-07 at Belatal (Chitrakoot Div.) under restricted irrigated and at Bharari Jhansi (Jhansi Div.) under irrigated condition of Bundelkhand. The results indicated that the varieties differed significantly for grain and straw yield due to sowing times in both Parwa and Kabar soils under restricted irrigated and irrigated conditions. Delayed sowing causes maximum reduction under restricted irrigated condition. The variety K 8027 responded better in comparison to other varieties for normal sowing and K 8962 for late sowing times in both of the soils under restricted irrigated condition. Similarly under irrigated condition, the variety K 9107 for mid Nov. and PBW 343 for mid to end of Nov. under Parwa soil and Raj 3765 for all sowing dates (normal to late) under both of the soils were found more effective for grain as well as straw yield. Therefore, these varieties should be selected as most effective performers for successful cultivation under varying agro-climatic conditions of Bundelkhand.

Wheat is the stable food crop, and is extensively grown under varying climatic condition i.e., in light (Parwa) and heavy (Kabar) types of soil under varying levels of irrigation facilities. There are more areas falling under restricted irrigation (one to two irrigation facilities) (proving irrigation through canal) and irrigation levels maximum up to 3 or 4 (providing through pump set, tube wells or ponds etc.). There is also considerable area in Chitrakoot Div. after paddy, and in Jhansi Div. after sorghum and other late maturing crops, causes delayed sowing of wheat crop. As a result, the crop gets exposed to higher ambient temperature at the time of grain filling period, which causes significant reduction in grain productivity of wheat crop. Singh *et al.*, (2009) has been reported that limited irrigation facilities and high temperature during grain filling period are the major constraints of low productivity in Bundelkhand. Several varieties have been released as suitable separately under restricted irrigated and irrigated conditions as well as normal and late sown conditions. Due to unfavourable weather condition, there is urgent need to judge such varieties under such conditions in Bundelkhand. Therefore, recommended varieties under limited irrigated and irrigated conditions at both normal and late sown situations were included to judge the feasibilities under varying agro-climatic conditions of Bundelkhand.

## MATERIAL AND METHODS

The present study comprised of 8 varieties, namely, K 8027, K 8962, K 9465, K 9162, HDR 77, A 9-30-1 and HW 2004 for restricted irrigated and ten i.e., K 9107, UP 2338, PBW 373, PBW 343, RAJ 3765, HUW 234, K 9533, NW 1014, K 8020 and WH 147 for irrigated condition were conducted during winter 2006-07. The experiment under restricted irrigated condition was laid out in both of the soils at Zonal Agriculture Research Station, Belatal (Mahoba) in

Chitrakoot Div. and under irrigated condition in both of the soils at Regional Research Station Bharari Jhansi in Jhansi Div. of Bundelkhand. The experiment were conducted in split plot design with 3 replications considering dates of sowing i.e., 10$^{th}$ Nov., 25$^{th}$ Nov. and 10$^{th}$ Dec. as main plot and varieties as subplot under both of the soils in both of the irrigation levels. Recommended dose of fertilizers separately under restricted irrigated and irrigated conditions were used. All the intercultural operations were adopted as per need of the crop. Grain and straw yields of each of the experiments were recorded at maturity.

## RESULT AND DISCUSSION

Grain yield differed significantly due to dates of sowing in both of Parwa and Kabar soils under both of the irrigation levels i.e., limited irrigated and irrigated conditions. On an average, maximum grain yield and straw yield, respectively were recorded at I$^{st}$ sowing date (10$^{th}$ Nov.) i.e., 38.8 q/ha and 58.2 q/ha in Parwa and 41.2 q/ha and 60.7 q/ha in Kabar soils under limited irrigated condition. Similarly maximum average grain and straw yields were also found at the same date of sowing i.e., 50.0 q/ha and 71.4 q/ha in Parwa and 48.2 q/ha and 69.9 q/ha in Kabar soil under irrigated condition. Higher grain yields have also been reported under irrigated condition than restricted irrigated condition under normal sowing condition by Singh *et al.* 2009. Seeing the effects of all of the three sowing dates, it was found that the grain and straw yields were significantly affected due to sowing time as well as varieties in both of the soils under both of the irrigation levels. Individually, the maximum grain (43.9 q/ha) and straw yield (65.4 q/ha) in Kabar soil were recorded under restricted irrigated condition at I$^{st}$ sowing date. Similarly, maximum grain (52.0 q/ha) in Kabar soil and straw yield (76.4 q/ha) in Parwa soil were also found under irrigated condition at I$^{st}$ sowing date.

**Table 1. Effect of sowing date and variety on grain yield under limited irrigated condition (2 irrigations)**

| Varieties | | Parwa Soil (sowing date) | | | | Kabar soil (sowing date) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $D_1$ | $D_2$ | $D_3$ | Mean | $D_1$ | $D_2$ | $D_3$ | Mean |
| 1. | K 8027 | 41.7 | 38.5 | 30.2 | 36.8 | 43.5 | 40.2 | 31.2 | 38.3 |
| 2. | K 8962 | 38.1 | 38.6 | 33.4 | 36.7 | 39.2 | 38.5 | 36.5 | 38.1 |
| 3. | K 9465 | 37.2 | 36.2 | 31.2 | 34.9 | 38.4 | 36.2 | 33.6 | 36.1 |
| 4. | K 9644 | 38.4 | 34.5 | 29.4 | 34.1 | 43.9 | 40.5 | 30.1 | 38.2 |
| 5. | K 9162 | 40.5 | 36.6 | 30.2 | 35.8 | 42.2 | 38.2 | 30.0 | 36.8 |
| 6. | HDR 77 | 37.2 | 36.7 | 28.4 | 34.1 | 39.5 | 36.5 | 29.5 | 35.2 |
| 7. | A 9-30-1 | 36.5 | 34.1 | 29.6 | 33.4 | 40.5 | 35.2 | 31.9 | 35.9 |
| 8. | HW 2004 | 41.1 | 37.3 | 30.1 | 36.2 | 42.0 | 38.5 | 30.5 | 37.0 |
| | Mean | 38.8 | 36.6 | 30.3 | - | 41.2 | 38.0 | 31.7 | - |
| | CD P = 0.05 | D 2.0 | V 0.9 | | D x V 2.1 | D 0.6 | V 0.9 | | D x V 1.6 |

The results of the present study indicated that there was varying degree of reduction due to delayed sowing under each of the soil conditions and irrigation levels. On an average, there was minimum reduction in grain yield i.e., 5.5% in Parwa and 7.7% in Kabar soil from I$^{st}$ sowing (10$^{th}$ Nov.) to 2$^{nd}$ sowing time (25$^{th}$ Nov.), under restricted irrigated condition, but there was drastic reduction in grain yield i.e., 22-23% from 1$^{st}$ to 3$^{rd}$ sowing date (10$^{th}$ Dec.). Comparatively less reduction was recorded under irrigated condition, then restricted irrigated with delaying of sowings. Under irrigated condition, the reduction in grain yield was 5.2% in Parwa and 6.1% in Kabar soil from 1$^{st}$ to 2$^{nd}$ sowing, and 16.6% in Parwa and 19.5% in Kabar soil from 1$^{st}$ to 3$^{rd}$ sowing date. Almost similar trend was also recorded for straw yields also. The late sown wheat crop was supposed to be highly affected due to rise of temperature during reproductive phase period, which affected reduction in phenological and yield component characters, which ultimately caused reduced grain and straw yield of wheat crop. Lowest grain yield has also been reported under late sown condition by Dutta *et al.* (2005) Kumar *et al.* (2006) and Kumar and Pal (2009) in wheat.

The varieties differed significantly with respect to grain yield and straw yield. The interaction of sowing dates and varieties indicated that the variety K 8027 responded better having higher grain and straw yield in both of the soils under restricted irrigated condition, in both 1$^{st}$ and 2$^{nd}$ sowing dates. However, K 9644 gave highest grain yield only in Kabar soil at both of the above sowing dates. On the other hand K 8962 produced highest grain yield i.e., 33.2 q/ha and 36.5 q/ha, and straw yield i.e., 50.2 q/ha and 53.29 q/ha respectively under Parwa and Kabar soils in restricted irrigated condition at 3$^{rd}$ sowing date. Thus K 8027 was found best variety for mid Nov. to end of Nov. and

**Table 2. Effect of sowing date and variety on grain yield under irrigated condition (4 irrigations)**

| Varieties | | Parwa Soil (sowing date) | | | | Kabar soil (sowing date) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $D_1$ | $D_2$ | $D_3$ | Mean | $D_1$ | $D_2$ | $D_3$ | Mean |
| 1. | K 91.07 | 51.1 | 42.3 | 33.8 | 42.4 | 45.6 | 46.8 | 32.8 | 41.7 |
| 2. | UP 2338 | 50.1 | 40.0 | 39.4 | 43.2 | 49.3 | 45.4 | 41.0 | 45.2 |
| 3. | PBW 373 | 50.2 | 50.1 | 46.2 | 48.8 | 49.8 | 46.5 | 40.0 | 45.4 |
| 4. | PBW 343 | 51.5 | 52.6 | 38.5 | 47.5 | 49.0 | 45.1 | 34.5 | 42.9 |
| 5. | Raj 3765 | 50.1 | 47.1 | 46.3 | 47.8 | 52.0 | 48.3 | 43.1 | 47.8 |
| 6. | HUW 234 | 50.1 | 50.2 | 45.5 | 48.6 | 47.9 | 47.5 | 42.6 | 45.8 |
| 7. | K 9533 | 48.5 | 47.2 | 42.2 | 46.0 | 45.5 | 43.2 | 42.2 | 43.6 |
| 8. | HW 1014 | 49.5 | 50.1 | 47.5 | 49.0 | 46.2 | 40.1 | 38.5 | 41.6 |
| 9. | K 8020 | 50.5 | 48.2 | 43.6 | 47.4 | 48.5 | 45.2 | 40.1 | 44.6 |
| 10. | WH 147 | 47.6 | 46.5 | 40.2 | 44.8 | 48.0 | 44.4 | 39.2 | 43.9 |
| | Mean | 50.0 | 47.4 | 42.3 | - | 48.2 | 45.3 | 39.4 | - |
| | CD P = 0.05 | D 0.7 | V 1.2 | | D x V 2.0 | D 0.7 | V 0.9 | | D x V 1.6 |

K 8962 for December sowing under both kinds of soil in limited irrigated condition of Bundelkhand. Almost similar results have been reported for these varieties under limited irrigated condition of Bundelkhand by Singh *et al.* (2008 and 2009).

Under irrigated condition PBW 343 (51.5 q/ha) followed by K 9107 and UP 2338 (each with 51.1 q/ha) in Parwa soil and Raj 3765 (52.0 q/ha) in Kabar soil were performing better at 10th Nov. sowing date. On the other hand the varieties, NW 1014 (47.5 q/ha) followed by Raj 3765 (46.3 q/ha) and PBW 373 (46.2 q/ha) were found almost equally higher yielder in Parwa under late sown condition (10th Dec. sowing date). However under such condition the varieties Raj 3765 (43.1 q/ha) followed by HUW 234 (42.6 q/ha) and K 9533 (42.2 q/ha) were found superior in Kabar soil. Minimum reduction in grain yield was recorded i.e., 4.2% in NW 1014, 7.5% in Raj 3765, 7.9% in PBW 373 and 9.2% in HUW 234 in Parwa soil and 7.2% in K 9533 and 11.1% in HUW 234 in Kabar soil from 1st sowing to 3rd sowing dates under irrigated condition. Almost similar results were also recorded for straw yield.

On the basis of present findings, it is concluded that the varieties, K 9107 registered as good variety for Nov. sowing and PBW 343 from Mid Nov. to end of Nov. in Parwa soil under irrigated condition. K 9107 and PBW 343 have also been reported high yielding under normal sown irrigated condition by Singh et al. (2009 I, II). Considering grain and straw yield performance over all the three sowing dates, the varieties PBW 373, Raj 3765, HUW 234 and NW 1014 in Parwa and Raj 3765 in Kabar soil were found superior for cultivation under varying agro-climatic conditions of Bundelkhand.

1-DIHAR-DRDO C/o 56 APO

2-KVK Unnao

3- KVK Sahajahanpur (U.P)

**Table 3. Effect of sowing date and variety on straw yield under limited irrigated condition**

| Varieties | | Parwa Soil (sowing date) | | | | Kabar soil (sowing date) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $D_1$ | $D_2$ | $D_3$ | Mean | $D_1$ | $D_2$ | $D_3$ | Mean |
| 1. | K 8027 | 62.5 | 56.5 | 45.4 | 54.8 | 65.4 | 58.2 | 46.8 | 56.8 |
| 2. | K 8962 | 58.6 | 57.7 | 50.2 | 55.5 | 62.4 | 60.3 | 53.2 | 58.6 |
| 3. | K 9465 | 55.8 | 54.6 | 46.9 | 52.4 | 56.5 | 54.2 | 48.5 | 53.0 |
| 4. | K 9644 | 54.6 | 52.4 | 40.2 | 49.1 | 61.2 | 58.0 | 45.2 | 54.8 |
| 5. | K 9162 | 59.8 | 54.5 | 42.3 | 52.2 | 60.4 | 57.2 | 42.2 | 53.2 |
| 6. | HDR 77 | 56.2 | 54.4 | 40.1 | 50.2 | 58.6 | 54.2 | 40.4 | 51.0 |
| 7. | A 9-30-1 | 58.6 | 55.4 | 41.4 | 51.8 | 60.4 | 56.2 | 45.4 | 54.0 |
| 8. | HW 2004 | 60.2 | 56.4 | 42.2 | 52.9 | 61.4 | 58.6 | 44.7 | 54.9 |
| | Mean | 58.2 | 55.2 | 43.9 | - | 60.7 | 57.1 | 46.3 | - |
| | CD P = 0.05 | D<br>1.50 | V<br>0.10 | | D x V<br>2.50 | D<br>1.20 | V<br>0.80 | | D x V<br>1.8 |

**Table 4. Effect of sowing date and variety on straw yield under irrigated condition**

| Varieties | | Parwa Soil (sowing date) | | | | Kabar soil (sowing date) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $D_1$ | $D_2$ | $D_3$ | Mean | $D_1$ | $D_2$ | $D_3$ | Mean |
| 1. | K 9107 | 76.2 | 65.2 | 51.2 | 64.2 | 68.9 | 70.4 | 58.6 | 63.3 |
| 2. | UP 2338 | 76.4 | 64.3 | 63.1 | 67.9 | 72.0 | 69.2 | 64.6 | 68.6 |
| 3. | PBW 373 | 74.2 | 73.4 | 66.2 | 71.2 | 71.5 | 68.6 | 63.4 | 67.8 |
| 4. | PBW 343 | 71.4 | 72.6 | 58.3 | 67.4 | 69.6 | 64.2 | 52.6 | 62.1 |
| 5. | Raj 3765 | 70.2 | 66.4 | 57.4 | 64.6 | 73.0 | 68.6 | 65.1 | 68.9 |
| 6. | HUW 234 | 70.8 | 71.1 | 65.6 | 69.1 | 69.6 | 69.2 | 63.4 | 67.4 |
| 7. | K 9533 | 68.6 | 70.2 | 61.4 | 66.7 | 67.7 | 65.5 | 64.2 | 65.8 |
| 8. | HW 1014 | 71.4 | 73.4 | 68.5 | 71.1 | 68.5 | 62.2 | 60.1 | 63.6 |
| 9. | K 8020 | 72.5 | 68.5 | 60.4 | 67.0 | 70.6 | 66.4 | 61.2 | 66.0 |
| 10. | WH 147 | 62.4 | 60.6 | 55.4 | 59.4 | 68.5 | 65.2 | 59.1 | 64.2 |
| | Mean | 71.4 | 68.5 | 60.7 | - | 69.9 | 66.05 | 60.4 | - |
| | CD P = 0.05 | D 1.70 | V 0.9 | | D x V 2.5 | D 1.60 | V 1.10 | | D x V 2.3 |

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# RELATIVE PERFORMANCE OF SOME RICE BASED INTEGRTAED FARMING SYSTEMS IN NORTH EASTERN COASTAL PLAIN ZONE OF ODISHA

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## Abstract

The study on the relative performance and economic profitability of some rice based farming systems was carried out in the North eastern coastal plain zone of Odisha based on the primary data collected from 10 sample villages of Bhadrak district of the state. The findings of the study revealed that among the marginal category of farmers Rice + Fruits/ Vegetable+ Pisciculture is the predominant farming system adopted by 32 % of the respondent and resulted in highest net income of 83,940.00/ ha, B:C ratio of 2.57 and system productivity of 109.9 q REY/ha. However, among the small farmers though Rice + Fruits/Vegetable + Dairy + Pisciculture is the most prevalent farming system, maximum net income (76,860.00/ha), B:C ratio (2.42) and system productivity (104.8 q REY/ha) was found in Rice + Oil seed /Pulses+ Fruits/Vegetable+ Piscicultur system. Similarly, majority of the medium farmers though adopted Rice + Fruits/Vegetable + Dairy + Pisciculture system, highest net income (74,300.00/ha), B:C ratio (2.38) and system productivity (112.03 q REY/ ha) was noticed in Rice + Fruits/Vegetable+ Pisciculture+ Duckery IFS model. It was also observed that in all the categories of farmers, integration of pisciculture and horticulture with rice maximize the system productivity and profitability, enhanced resource cycling and generated additional employment opportunities.

**Key words**: Farming system, system productivity, gross return, net return and B:C ratio

During last few years the average land holdings in rural areas has been declining very rapidly and number of small and marginal farmers has been increasing. This trend is more increasingly noticed in the coastal areas compared to the inland districts owing to the high population density, migration pressure, industrialization and urbanization. With limited scope in horizontal expansion in farming, vertical expansion through judicious integration of appropriate farming components (Integrated Farming System, IFS) is the only option left for ensuring the food and livelihood security of the resource poor small and marginal farmers as single commodity based farming activities can not support multiple need of the family in a sustainable manner. Therefore, under the gradual shrinking of land holding, it is necessary to integrate land based enterprises like fishery, poultry, duckery, apiary, field and horticultural crops, etc. within the bio-physical and socio-economic environment of the farmers to make farming more profitable and dependable (Behera *et al.*, 2004). Radhammani *et al.* (2003) describes IFS's as a component of farming systems which takes into account the concepts of minimizing risk, increasing production and profits whilst improving the utilization of organic wastes and crop residues.

Bhadrak is one of the coastal districts in the state of Odisha coming under North Eastern Coastal Plain Zone (NECPZ), where majority of the population depend on agriculture and allied sector for deriving their daily sustenance. The land distribution is unevenly distributed as out of the total farming community, 58.5% are marginal, 23.4% are small, 17.9% are medium and only 0.2% are large farmers. The marginal and small farmers share about 81.9% of the total farm families and possess only 49.4% of total cultivable land. Besides, there is a growing disparity between the expanding population and the food producing capacity of the available land and as a result, per capita food availability is decreasing continuously endangering the food security of these vulnerable farm families. Frequent occurrence of natural disasters, mid-seasonal climatic aberrations, insect pest outbreak, increasing cost of external agro-inputs and market uncertainties are further intensifying the problem. In this context adoption of farming system approach is of immense significance to address the multiple and interwoven problems of farming community and to ensure their food, nutrition and livelihood security. As rice cultivation is the principal farming activity in the district, occupying 1,58,793 ha (90.22 % of total cultivable area) during kharif and 15,620 ha during summer season, KVK Bhadrak has been popularizing different rice based farming system models for different categories of farmers to sustain the livelihood of the farming community. The present study has been carried to evaluate the economic profitability and viability of different rice based farming systems in the district.

## Materials and Methods

The study was undertaken in 10 villages coming under different agro-ecological situations of the district. Fifteen farmers in each village belonging to different land holding categories (five each from marginal, small and medium category) were included in the study, thereby making the total sample size of 150. Marginal farmers possessed around 0.8 ha land, whereas, small and medium farmers have generally 1.6 and 2.4 ha land respectively. A well structured and pre-tested personal interview schedule was used to collect the data during 10th November to 24th December 2011. Information was collected through personal interview technique and the collected data were analyzed. The study was conducted with two objectives; the first one was to identify the popular farming systems in the sample area, while that of the second was to work out the system productivity and economic performance of major farming systems. The system productivity was expressed as Rice Equivalent Yield per hectare (REY/ha) and was computed by dividing the gross income/ha by the MSP of rice. The relative profitability was analyzed by considering the net return/ha, B:C ratio and self sufficiency index. Self sufficiency index was estimated to evaluate the financial stability of different farming system models and was calculated as [ Net return/ha (₹) × Landholding (ha) )/ Annual family requirement ()]. The minimum annual family requirement for six members to lead a healthy and decent living was fixed as Rs. 48,000.00 considering the opinion of the farmers and prevalent market price. The four major farming systems in each category based on highest per cent of adoption were considered for further analysis related to productivity and profitability.

## Results and Discussions

The findings of the study (Table 1) reveled that among the marginal category, Rice + Fruits/Vegetable + Pisciculture is the predominant farming systems adopted by 32 % of the respondents followed by Rice + Dairy + Pisciculture (21 %), Rice+ Dairy + Poultry (18 %) and Rice + Fruits /Vegetable + Mushroom (16 %). However, majority of the small farmers practiced Rice + Fruits/Vegetable + Dairy + Pisciculture integrated system (34 %) followed by Rice - Oil seed /Pulses+ Fruits/ Vegetable+ Pisciculture (25 %), Rice - Oilseed/Pulses + Fruits/Vegetables + Poultry (19 %) and Rice + Fruits/ Vegetable + Mushroom (12 %). Similarly, among the medium farmers, Rice + Fruits/Vegetable + Dairy + Pisciculture is the most preferred system (29 %) followed by Rice + Fruits/Vegetable + Pisciculture+ Duckery (25 %), Rice - Oil seed /Pulses+ Fruits/Vegetable + Poultry (21 %) and Rice - Oilseed/Pulses + Fruits/Vegetables + Apiary(10 %). Hence, it can be concluded that pisciculture and horticulture have been the most preferred allied enterprises in the rice based farming system owing to their suitability and profitability.

From the study it was found (Table 1) that among the marginal farmers Rice + Fruits/Vegetable + Pisciculture farming system model registered highest system productivity of 109.9 q REY/ha with maximum net return of 83,940.00/ ha and B:C ratio of 2.57 followed by Rice + Fruits/Vegetable + Mushroom with productivity of 101.0 q REY/ha, net return of 70,400.00 and B:C ratio of 2.26. . However, Rice+ Dairy + Poultry integrated system resulted in lowest productivity of 84.8 q REY/ha with minimum net return ( 47,730.00) and B:C ratio (1.82). The self sufficiency index was calculated to be highest in Rice + Fruits/Vegetable + Pisciculture integrated farming system, whereas, its lowest value (0.80) was found in the Rice+ Dairy + Poultry system. In the small category of land holders maximum system productivity (104.5 q REY/ha), net return (76,860.00/ha) and B:C ratio (2.42) were noticed in the Rice - Oil seed /Pulses+ Fruits/Vegetable+ Pisciculture farming system closely followed by Rice + Fruits/Vegetable + Dairy + Pisciculture IFS model (system productivity of 103.3 q REY/ha, net income of 72,500.00/ha and B:C ratio of 2.28). On the other hand Rice - Oilseed/Pulses + Fruits/ Vegetables + Poultry registered lowest productivity (87.3 q REY/ha) and profitability (net return of 58,600.00/ha and B:C ratio of 2.16). Similarly, the self sufficiency index value was estimated to be highest (2.56) in the most productive and profitable farming system model. Among the medium holders Rice + Fruits/Vegetable+ Pisciculture + Duckery farming system model has been found to be the most productive (103.0 q REY/ha) and profitable (net return of 72,700.00/ha and B: C ratio of 2.30) closely followed by Rice + Fruits/ Vegetable + Dairy + Pisciculture farming system model with productivity of 102.4 q REY/ha, net return of 66397.00/ha and B:C ratio of 2.18. The lowest productivity and profitability was observed in Rice - Oil seed /Pulses+ Fruits/Vegetable + Poultry system. The self sufficiency index has been invariably higher among the medium farmers due to better resource endowment indicated their financial stability. However, highest index value was obtained from Rice + Fruits/Vegetable + Pisciculture + Duckery (3.64) followed by Rice + Fruits/ Vegetable + Dairy + Pisciculture (3.47).

As residue recycling and employment generation have been the underlying principles of IFS, efforts were also made to study the amount of internal inputs generated and additional employment opportunities created in different farming system models. Among the marginal

**Table 1. Major rice based integrated farming systems and their economic analysis**

| Sl. | Farmers Category | Rice based Integrtaed Farming Systems | Frequency (%) | Gross Income (`)/ha | Gross expenditure (`)/ha | Cost of internal inputs generated (`)/ha | Net Income (`)/ha | B:C Ratio | Additional employment generate/ year | System productivity (REY) (q/ha) | Net Income (`)/ system | Self Sufficiency Index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Marginal | Rice + Fruits/ Vegetable+ Pisciculture | 32 | 137405 | 53465 | 9400 | 83,940 | 2.57 | 325 | 109.9 | 67152 | 1.40 |
| 2 | Marginal | Rice + Dairy + Poultry | 18 | 105937 | 58207 | 4500 | 47,730 | 1.82 | 180 | 84.8 | 38184 | 0.80 |
| 3 | Marginal | Rice + Dairy + Pisciculture | 21 | 113515 | 50905 | 7800 | 62,610 | 2.23 | 230 | 90.8 | 50088 | 1.04 |
| 4 | Marginal | Rice + Fruits/Vegetable + Mushroom | 16 | 126273 | 55873 | 6200 | 70,400 | 2.26 | 380 | 101.0 | 56320 | 1.17 |
| 5 | Small | Rice + Fruits/Vegetable + Dairy + Pisciculture | 34 | 129140 | 56641 | 8200 | 72,500 | 2.28 | 255 | 103.3 | 116000 | 2.42 |
| 6 | Small | Rice - Oilseed/Pulses + Fruits/Vegetables + Poultry | 19 | 109117 | 50517 | 4200 | 58,600 | 2.16 | 160 | 87.3 | 93760 | 1.95 |
| 7 | Small | Rice - Oil seed /Pulses+ Fruits/Vegetable+ Pisciculture | 25 | 130987 | 54126 | 5700 | 76,860 | 2.42 | 220 | 104.5 | 122976 | 2.56 |
| 8 | Small | Rice + Fruits/Vegetable + Mushroom | 12 | 126255 | 57915 | 5100 | 68,340 | 2.18 | 310 | 101.0 | 109344 | 2.28 |
| 9 | Medium | Rice + Fruits/Vegetable + Dairy + Pisciculture | 29 | 127957 | 58620 | 4800 | 69,337 | 2.18 | 220 | 102.4 | 166401 | 3.47 |
| 10 | Medium | Rice - Oil seed /Pulses+ Fruits/Vegetable + Poultry | 21 | 102544 | 50160 | 3500 | 52384 | 2.04 | 130 | 82.03 | 125722 | 2.62 |
| 11 | Medium | Rice + Fruits/Vegetable + Pisciculture + Duckery | 25 | 128540 | 55840 | 6600 | 72,700 | 2.30 | 145 | 103.0 | 174480 | 3.64 |
| 12 | Medium | Rice - Oil seed/ Pulse + Fruits/Vegetable +Apiary | 10 | 104600 | 48900 | 3900 | 55,700 | 2.14 | 125 | 83.7 | 133680 | 2.79 |

farmers maximum internal inputs generated in the Rice + Fruits/ Vegetable+ Pisciculture model (9400/ ha), whereas, highest number of employment created in Rice + Fruits/ Vegetable + Mushroom system (380/ year). In the small category maximum residue cycling was observed in Rice + Fruits/Vegetable + Dairy + Pisciculture IFS model (cost of internal inputs = 8200.00/ha) but highest number of family labours engaged in Rice + Fruits/ Vegetable + Mushroom system (310/ year). However, among the medium farmers extent of residue recycling was highest in Rice + Fruits/Vegetable + Pisciculture + Duckery model (cost of internal inputs = 6600.00/ha) and maximumadditional mandays created in Fruits/Vegetable + Dairy + Pisciculture IFS model (220/year).

The results are in partial agreement with the findings of Channabasavanna and Biradar (2007) who reveled that rice-fish-poultry models recorded the highest system productivity ( 175.02 q REY/ha) and net returns (62977/ha) compared to conventional rice-rice system with 66.67 q REY/ha and 21,599/ha sytem productivity and net return, respectively. They also opined that an additional employment of 41.4 per cent was generated in IFS approach.

## CONCLUSION

From the above study it can be suggested that for all the categories of farmers, integration of pisciculture and horticulture with rice can maximize the system productivity and profitability. For the small and marginal farmers mushroom can be a viable component of rice based farming system that can increase the net income and generate employment opportunities for the family members. However, the profitability from dairy component has not been encouraging due to high cost of cattle feed and low market price of milk and milk products , which necessitates more focus on the development of low cost cattle feed and value added products from milk. It can also be concluded that the adoption of rice based farming systems over the mono and multiple cropping system has substantially increased the net income of the farmers per unit area and largely contributed towards their livelihood security. The farming system approach also minimized the input cost through residue recycling (secondary produces of one component are used as the basic inputs of the other component), thereby increased the benefit: cost ratio of the system as a whole. It was also observed that farming systems practiced in the study area are greatly influenced by the resource base, food habit and social beliefs of the farmers.

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