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Influence of organic matter on retention and release of lead in a semi-arid soil from India

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ABSTRACT

Lead adsorption/desorption studies were carried out on a soil sample derived from a long-term manurial trial, receiving 30 t/ha of well decomposed farm yard manure (FYM) per annum since 1967. Results were compared with a sample from the adjoining field undergoing similar cropping activities minus FYM. The samples were equilibrated with lead (Pb) concentrations varying from 5-500 µM L^{-1} at a total electrolyte concentration of 500 µM L^{-1}. The quantities of Pb sorbed increased with equilibrating Pb concentration but the sorption was relatively higher at its lower concentrations. Also, high organic matter (OM) soil retained more Pb in comparison to low OM soil. Power function best described the sorption at low Pb concentrations, whereas linear function was the best fit at high concentrations. Langmuir adsorption was resolved into two components to obtain a linear relationship. The bonding energy and sorption maxima values were higher in high OM soil. Contrary to Langmuir plots, the Freundlich plots were linear at all concentrations and high affinity values for Pb further confirmed the conclusion drawn in Langmuir equation on bonding energy. Neutral salt solutions could extract only a fraction of the sorbed Pb indicating its precipitation. High OM soil tended to maintain high Pb in solution contradicting the earlier belief that OM could be sink for heavy metal ions.

Key words : Pb sorption, organic matter, desorption, semi-arid soil, FYM

INTRODUCTION

There has been an increase in heavy metal concentrations in agro-ecosystems as a result of rapid urbanisation and enhanced industrial growth. With the use of sewage waters for irrigation around the cities and sewage sludge as manure, the load of pollutants and nonessential ions in foodchain has gone up dramatically. In some parts of Haryana (India), recent reports (Gupta et al., 1986; Haroon and Ramulu, 1990 and Hooda and Alloway, 1994) indicated that there has been a build up of lead in the soils. To keep the food and fodder fit for human or livestock's consumption, it is necessary that the toxic elements are maintained within permissible and/ or safe limits. Adsorption/ desorption studies are important tools to understand the heavy metal ion behaviour in soils. Organic matter with its ability to chelate and formation of soluble complexes may influence the retention or release of such ions. With the growing emphasis on "Organic farming", such studies gain further importance.

MATERIALS AND METHODS

Soil samples (0-20 cm) from plots of a long-term manurial trial in operation since 1967, receiving 30 t/ha farm yard manure (FYM) per annum, were collected from the Research Farm of CCS Haryana Agricultural University, Hisar in 2008. The cropping sequence was millets-wheat. As a result of continuous additions, the soil organic content (OC) has gone up considerably from its initial level of 0.47% in 1967. For comparison, a soil sample from an adjoining field undergoing the same cropping sequence but without FYM application was also collected. The soil samples were processed and analysed for physico-chemical characteristics (Table 1) determined using standard methods as per Jackson (1967).

A portion of the samples was made homoionic through repeated washings with 1 M $CaCl_2$ solution and excess salts were removed by giving three washings each with distilled water and 95% ethanol and two washings with petroleum ether as mentioned in the sequence.

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Table 1. Physico-chemical properties of the experimental soils

	pH (1 : 2)	EC (dS/m^{-1})	Org. C (%)	CEC cmol (p=) kg^{-1}	Clay (%)	DTPA -Pb ($\mu g/kg^{-1}$)
Soil 1	7.5	0.82	1.25	12.26	10.0	10
Soil 2	7.8	0.23	0.51	10.80	8.5	10

A set of solutions having constant electrolyte concentration of 500 $\mu M\ L^{-1}$ but varying in Pb concentration between 5-500 $\mu M\ L^{-1}$, were prepared. Five grams of homoioinic soil was equilibrated with 50 ml of the Pb solution for 24 hours (with intermittent shaking). After equilibration, the suspensions were centrifuged and supernatant solution filtered and preserved for analysis on atomic absorption spectrophotometer. The quantity of Pb retained was calculated by difference. The data were tested to fit the Langmuir and Freundlich adsorption equations.

Soil residues left after equilibration with Pb solutions of >180 $\mu M\ L^{-1}$ concentration were selected for desorption study. The soil residue was shaken with 50 ml of 0.01M $CaCl_2$ for 10 min. and centrifuged. The clear supernatant solution was analysed for Pb. This process was repeated four times. Necessary corrections were made for entrapped solution and its Pb content.

RESULTS AND DISCUSSION

The quantities of sorbed Pb increased with its increasing concentration in the equilibrating solution in both the soils but the relative sorption was higher at low Pb equilibrating solution concentrations. Also, the high organic matter soil retained more Pb at all Pb concentrations as compared to low organic matter soil. The adsorption data was regressed using several adsorption equations and it was observed that at low Pb concentrations, its sorption was best described by the Power function equation (Fig.1) but at high concentration, the linear regression was found the best fit. The high R^2 values for part I (0.92, 0.93) and part II (0.99, 0.98) further established the said fit of the equation for the soils.

When the data was plotted as per Langmuir equation, which read as:

$$C/(X/m)=1/(BD)+C/B$$

where C is equilibrium Pb concentration in the

Table 2. Pb adsorption constants

Soil No.	Langmuir constants			
	Adsorption maxima (B) ($\mu mole\ 100\ g^{-1}$)		Bonding energy (D) ($l\ \mu mole^{-1}$)	
	Part-I	Part-II	Part-I	Part-II
1	133.3	0.15	322.6	$2.67x10^{-2}$
2	102.0	0.10	212.7	$1.97x10^{-2}$
Freundlich constants				
	K		n	
1	2.0301		2.016	
2	1.9771		2.193	

Table 3. Desorption of Pb in different extractions with $CaCl_2$ solution

Added Pb ($\mu M\ L^{-1}$)	Sorbed Pb ($\mu M\ 100\ g^{-1}$)	Pb desorbed ($\mu M\ 100\ g^{-1}$)					Desorption (%)
		No. of extraction				Total	
		I	II	III	IV		
High OM soil							
180	144.4	19.0	14.3	2.2	2.0	37.5	26.0
260	198.0	26.8	19.8	6.3	3.5	56.4	28.4
340	247.5	36.0	25.0	10.3	8.4	79.7	32.2
420	272.0	45.0	31.2	14.2	10.2	100.6	37.0
500	275.0	49.0	36.4	15.2	11.0	111.6	40.6
Low OM soil							
180	127.0	12.4	8.0	3.8	2.4	26.6	21.0
260	165.2	16.0	10.0	7.6	4.4	38.0	23.0
340	200.1	25.0	14.0	7.0	3.0	49.0	24.5
420	220.0	30.8	16.2	7.5	4.0	58.5	26.6
500	226.0	36.4	18.6	7.6	5.0	67.6	29.7

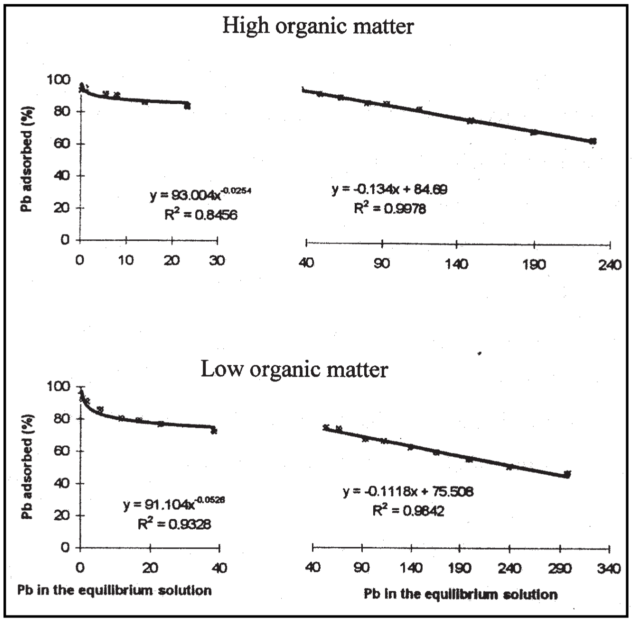

Fig. 1. Relationship between per cent Pb adsorbed and in equilibrium solution in soils varying in organic matter.

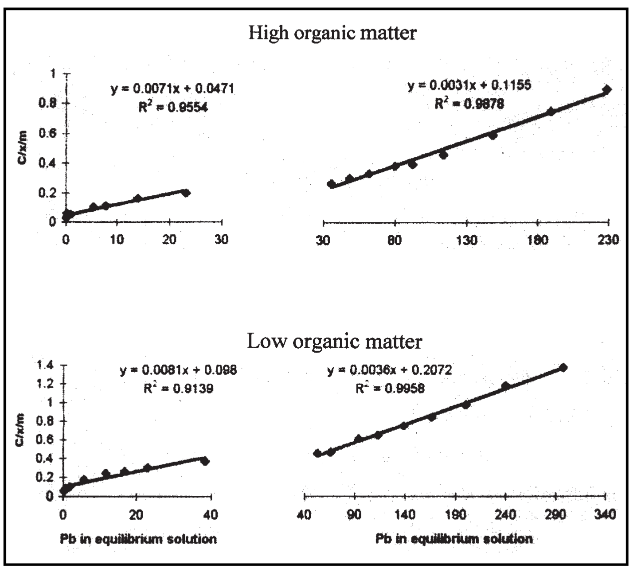

Fig. 2. Langmuir adsorption isotherms of Pb as influenced by organic matter.

equilibrium solution (µM L^{-1}), X/m is the quantity of Pb sorbed per unit soil weight (µM $100g^{-1}$), B is adsorption maxima (µM $100g^{-1}$) and D is the constant related to bonding energy (L μM^{-1}). Normally a plot of C/(X/m) versus C results in a straight line from which B (gradient) and D (gradient/ intercept) can be computed. Langmuir plot was best fit only when resolved into two parts, part I for low Pb concentration and part II for high Pb concentration (Fig. 2). The partitioning of the adsorption curve into two parts was done with the assumption that there existed two populations of sites that have different affinity for Pb. Harter and Baker (1977) stated that the commonly reported curvilinear nature of C/(X/m) versus C plot was simply due to not considering the effects of desorbed ion in the equilibrium solution. The Langmuir constants were computed for both the parts and soils (Table 2). It is evident that the bonding energy and adsorption maxima were relatively higher in soil rich in organic carbon (OC) possibly due to its chelating ability. Bhattacharyya and Poonia (2000) reported that the values of Langmuir parameters for Cd adsorption decreased on removal of organic matter. Elkhatib *et al*.(1993) reported that Pb sorption in calcareous soils followed the Freundlich and Langmuir equations and the influence of soil group was more evident in Langmuir equation. Adhikari and Singh (2000) showed that both these equations satisfactorily described the Pb and Cd sorption but a better fit was obtained upon modification of the Langmuir equation. The sorption maximum was found to be related to soil organic matter content, pH and CEC.

Freundlich (1926) gave an expression to describe the adsorption of ions or molecules from a liquid on to a solid surface by the expression :

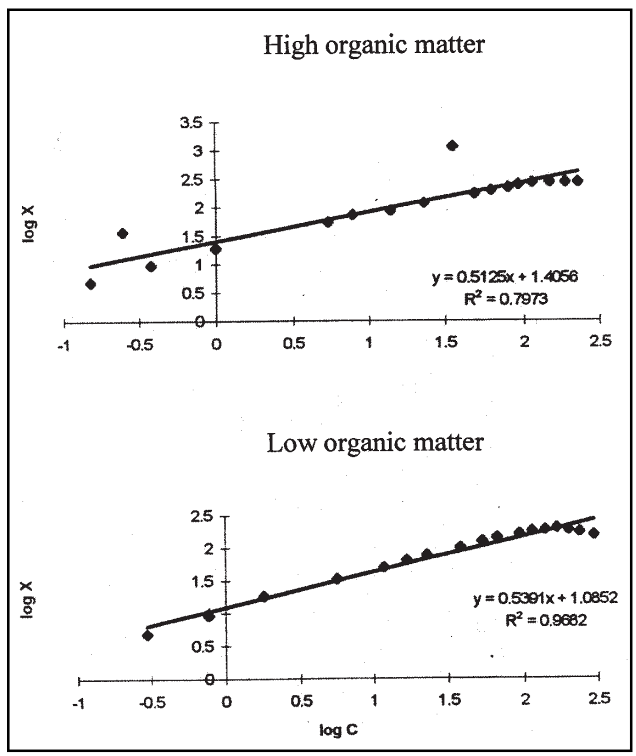

Fig. 3. Freundlich adsorption isotherms of Pb as influenced by organic matter.

$$X/m = K\,C^{1/n}$$

where X/m is the quantity of ion sorbed per unit weight of soil, C is equilibrium concentration of the ion in question. K and n are the constants that can be arrived at from the plot of log (X/m) vs C, which is linear with slope as 1/n and intercept as log K. Freundlich isotherms for both the soils were linear (Fig. 3) at all the Pb concentrations and Freundlich constants have been given in Table 2. The high K value (indicating the affinity of ion in question for the soil) further confirms the conclusion derived earlier based on Langmuir equation.

Desorption of Pb

As discussed earlier, the desorption studies were restricted to soil residues left after equilibration with Pb solution of >180 µM L^{-1}. Data presented in Table 3 revealed that maximum Pb could be extracted in the first two extractions and it decreased substantially thereafter. Moreover, in all the four extractions only a part (30-40%) of the sorbed Pb could be extracted and high organic matter soil desorbed more Pb. It implied that in such soils Pb could be retained in forms not easily extractable with dilute neutral salt solutions and could have been precipitated as hydroxides or carbonates as the soil pH values were in alkaline range. In non-calcareous soils, the solubility of Pb appears to be regulated by $Pb(OH)_2$, $Pb(PO_4)_3$, $Pb_3(PO_4)OH$, $PB_4O(PO_4)_2$ depending upon the pH (Santillan-Medrano and Jurinak,1975). A plot of equilibrating Pb concentration (Y) against per cent Pb desorbed (X) exhibited a linear relationship for both, low (Y=0.026 X + 16.04) as well as high organic matter soil (Y =0.047 X +16.78). It implied that at a particular Pb equilibration, high organic matter soil will tend not only to release more Pb into the soil solution (if the same is depleted) as evident from the high slope values, but also maintain more Pb as hinted by slightly high intercept values. It may have direct bearing on the hypothesis that heavy metal contaminated soils could be amended by adding organic matter. These results hinted that organic matter may serve as a sink for Pb but this sink would be a 'leaking sink' rather than an isolating one. But this needs further confirmation through experimentation on wider number of soils.

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Principal components analysis of kabuli chickpea (*Cicer arietinum*) genotypes under moisture stress

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ABSTRACT

The experiment was conducted in concrete micro plots filled with dunal sand at crop physiology field laboratory at CCS Haryana Agricultural University, Hisar Research Farm located at $29^0 10^0$N latitude, $75^0 46^0$E longitude and 215.2 M altitude. Five Kabuli chickpea genotypes namely HK00-300, HK99-214, HK98-155, HK00-290 and HK1 were tested in three stress environments i.e. severe stress (no post-sowing irrigation), mild stress (one irrigation at 70 DAS) and no-stress (two irrigation at 70 and 110 DAS) with four repeats in split plot design. The principal components analysis of seven yield characters of five genotypes indicate that the seed yield in irrigated environment was mainly explained due to variation in effective pods/plant and seeds/pod. Under mild stress environment by seeds/pod and biological yield where as under severe stress environment the yield variation are due to biological yield and pods /plant. Under irrigated environment genotype HK-1 and HK 98-155 yielded highest with maximum number of seeds/ pod. But under the mild stress treatment the higher seed yield of HK98-155 was due to the longer height of fertility zone and in HK-1 due to higher pod density. But under severe stress condition the higher seed yield of HK99-214 and HK00-290 was due to their higher pod density. The hierarchical cluster analysis indicates that all these genotypes were genetically close relatives.

Key words : Principal components analysis**,** moisture stress levels, kabuli chickpea genotypes and yield

INTRODUCTION

Chickpea commonly known as gram or Bengal gram is the third most important pulse crop in the world. India is the world's largest producer of chickpea with an area of 8.25 m ha with a productivity of 855 kg/ha (Jayalaxmi *et al*, 2011). Chickpea is a rich supplement to cereal based diet, especially to the poor in the developing countries, where people can not afford animal protein (or are vegetarian). Kabuli chickpea being rich in protein and used for culinary purposes have good potential for export as well. Low moisture availability is one of the most important yield limiting factor under conserved soil moisture condition. A characteristics feature of crop production in such areas is periodic water stress of varying duration and intensities during different growth phases. The differential response of genotypes under different environment may be due to variation in their physiological responses. Selection of genotypes tolerant to drought stress would be the most appropriate to improve productivity and can prove a boon to improve the economy of poor farmers of dryland areas of the country. Hence, Principal Components Analysis was done to identify variables or components that explain most of the variance between cases observed in a much larger number of yield variables.

MATERIAL AND METHODS

An experiment was conducted in concrete micro plots filled with dunal sand located at research farm of CCS Haryana Agricultural University, Hisar (at 29º10ºN latitude and 75º46ºE longitudes with an elevation of 215.2 m above mean sea level). The experiment was laid out in a split plot design with four replications. Experiment consisted of three environments of moisture in main plot i.e. severe stress (no post sowing irrigation), mild stress (one irrigation at 70 DAS) and no-stress (two irrigation at 70 and 110 DAS) with five genotypes in sub plots namely HK00-300, HK99-214, HK98-155, HK00-290 and HK-1. The crop was raised with recommended Package of Practices. For recording yield parameters five representative plants from each plot were sampled at harvest. The yield attributes viz height of fertility zone i.e. pod bearing length of stem was measured at the harvest of each sample with meter rod. Total number of branches and number of effective pods/ plant was counted at harvest for each treatment. After recording the dry weight of effective pods the plant sample were threshed separately. Total seeds were counted and then their total number was divided by total effective pods to compute seeds/pod. 100 seeds were counted from each sample and weighed for test weight for each treatment. The seed and biological yield were recorded at the time of maturity from the plot and converted to kg/ha.

Principal Components Analysis (PCA) is a multivariate technique that analyses a data table in which observations are described by several inter correlated quantitative dependent variables. It's goal is to extract the important information from the table, to represent it as a set of new orthogonal variables called principal components and to display the pattern of similarity of the observations and of the variables as points in maps (Abdi and Williams, 2010). Principal components analysis was done to reduce large correlation matrix into a much smaller set of correlations between independent components which still explains most of the variations between cases in the original matrix. The principal components (PCs) are linear combinations of the original variables. They are functions, where each variable is assigned a coefficient, lij, or factor loading, which explains both its importance in the principal component, and its relationship to other variables.

PCj = l1j V1 + l2j V2+………… + 1pj Vp

Where PCj is the jth principal component and V1 to Vp are the p variables that were measured. Principal components were calculated such that the 1st PC explains as much variation in the data set as possible, the 2nd PC is uncorrelated with the 1st PC, and explains as much of the remaining variation as possible, and so on. Essentially principal components analysis is a pattern recognition process. PC1 captures the trend along which, there is best discrimination between cases in the data set, while PC2 is a trend perpendicular to PC1 along which we get the next best discrimination between the cases, and so on until all the variation in the dataset has been explained. The maximum number of principle components were either the number of measured variables or one less than the number of cases, whichever number is smaller. The hierarchical cluster analysis is used to classify the entries from germplasm according to their degree of similarities or according to their respective gene pools and also to show the segregative potential of entries (Peeters and Martinelli,1989).

RESULTS AND DISCUSSION

Yield Attributes

The increase in moisture stress significantly decreased the height of fertility zone, number of effective pods/ plant and test weight than irrigated control. These attributes were statistically at par between mild and severe stress. (Table 1). However, number of seeds per pod were observed significantly lower in severe stress treatment than mild stress and irrigated control, which did not differ significantly.

Among the genotypes, number of effective pods/ plant, and number of seeds/ pod were recorded maximum for HK-1 followed by HK 98-155. The number

Table 1. Effect of moisture stress on yield attributes and yield of chickpea genotypes at harvest

Treatments	At harvest						
	Height of fertility zone	Total no. of branches/ plant	No. of effective pods/plant	No. of seeds/ pod	100-seed weight (g)	Biological yield (kg/ha)	Seed yield (kg/ha)
Severe stress	16.4	17.4	10.6	1.01	23.4	4124	904
Mild stress	16.6	16.1	12.0	1.13	24.1	4388	1028
Irrigated	25.2	17.7	22.0	1.11	29.7	7230	2007
CD at 5%	0.8	NS	2.8	0.04	1.1	162	27
HK 00-300	19.9	18.3	10.7	1.04	28.9	5229	1113
HK 99-214	17.5	19.8	13.6	1.02	26.7	5228	1303
HK 98-155	19.9	13.7	15.7	1.15	26.5	5252	1475
HK 00-290	20.4	17.2	13.7	1.02	30.0	4887	1311
HK-1	19.2	16.3	20.6	1.19	16.6	5642	1363
CD at 5%	1.5	2.2	2.0	0.06	1.8	32	48

of seeds/ pod was at par among HK00-300, HK99-214 and HK00-290. Test weight was observed highest in HK00-290 followed by HK00-300 and significantly lowers in HK-1 than all other genotypes. Similar variations in genotypes has also been reported by Gupta *et al.* (2000) and Sharma *et al.* (2007).

Yield

A perusal of data in Table 1 reveals that seed yield and biological yield were significantly higher under irrigated control than recorded under stressed environment. The drastic reduction of seed yield in mild (48.7%) and severe stressed treatment (54.9%) over irrigated control was mainly because of 48.9% and 55.6% reduction in pod density followed by test weight reduction to the tune of 18.8% and 21.2% respectively. Depending upon the degree of water shortage, seed yield was reduced by 50-80 % due to reduction in seed number and seed size. This indicates that pod setting is the most sensitive yield parameters to moisture stress at reproductive phase. This fact can also be ascertained from the significant reduction in height of fertility zone. This poor pod setting in stressed environment also resulted into poor partitioning to pod which resulted into significantly lower harvest and attraction index. The height of fertility zone (r=0.91) and number of effective pods/plant (r=0.86) were positively associated with seed yield. These results are also supported by Singh *et al* (2004).

Among the genotypes seed yield and biological yield were recorded maximum in HK 98-155 and HK1 respectively, which differed significantly from other genotypes. These two genotypes followed each other in seed and biological yield. The higher seed yield in these genotypes was mainly due to the significantly higher pod density and number of seeds/pod in HK-1 and number of pods/ plant and 100 seed weight in HK 98-155 (Table 1). Deshmukh *et al* (2004) also reported genotypic variability in yield due to higher number of pods/plants, seeds/plant, branches/plant and higher seed weight. Under the irrigated environment, seed yield was found highly associated with biological yield and effective pods/plant and negatively associated with test weight. The seed yield was associated with seeds/pod and height of fertility zone and negative association with total number of branches in the mild stress environment. Whereas, under severe stress condition, seed yield was found highly associated with biological yield and seed. These results are in conformity with Sharma *et al* (2007) and Rahman *et al* (2000).

Principle component analysis

The principle component analysis done with the seven important yield and yield attributes namely seed yield, biological yield, total number of branches, height of the fertility zone, effective pods/plant, 100-seed weight and seed/ pod for three growing environments. The factor loadings computed for different attributes along with the per cent variance explained by different principal components are given in Table 2. All the attributes were explained better from PC1 and PC2 except height of fertility zone in mild stress treatment and 100 seed weight and seeds/ pod under severe stress environment.

Under the irrigated environment the biplot analysis (Fig 1) indicate that PC-I explained the variation up to 48% and 21% in PC- 2. So, this biplot explain variation up to 69% in variance. But with the imposition of stress the variation in variance was reduced to 31.8, 25.8 and 57.6 % in mild stress and 31.6, 21.5 and 53.1 % in severe stress for PC-I, PC-2 and total of both, respectively.

Under the irrigated environment, seed yield was found highly associated with biological yield and effective pods/plant and negatively associated with test weight. The seed yield was associated with seeds/ pod and height of fertility zone and negative association with total number of branches in the mild stress environment. Whereas, under severe stress condition, seed yield was found highly associated with biological yield and seed. Looking into the vector length the seeds/pod followed by effective pod are most important yield attributes controlling the yield under irrigated and mild stress environment. Whereas, under severe stress environment number of effective pods/plant and height of the fertility zone was most important.

The plotting of genotypes score in the biplot indicate that under irrigated environment genotype HK-1 and HK 98-155 yielded highest with higher number of seeds per pod. But under the mild stress treatment the higher seed yield of HK98-155 was due to the longer height of fertility zone and in HK-1 due to higher pod density. But under severe stress condition the higher seed yield of HK99-214 and HK00-290 was due to their higher pod density.

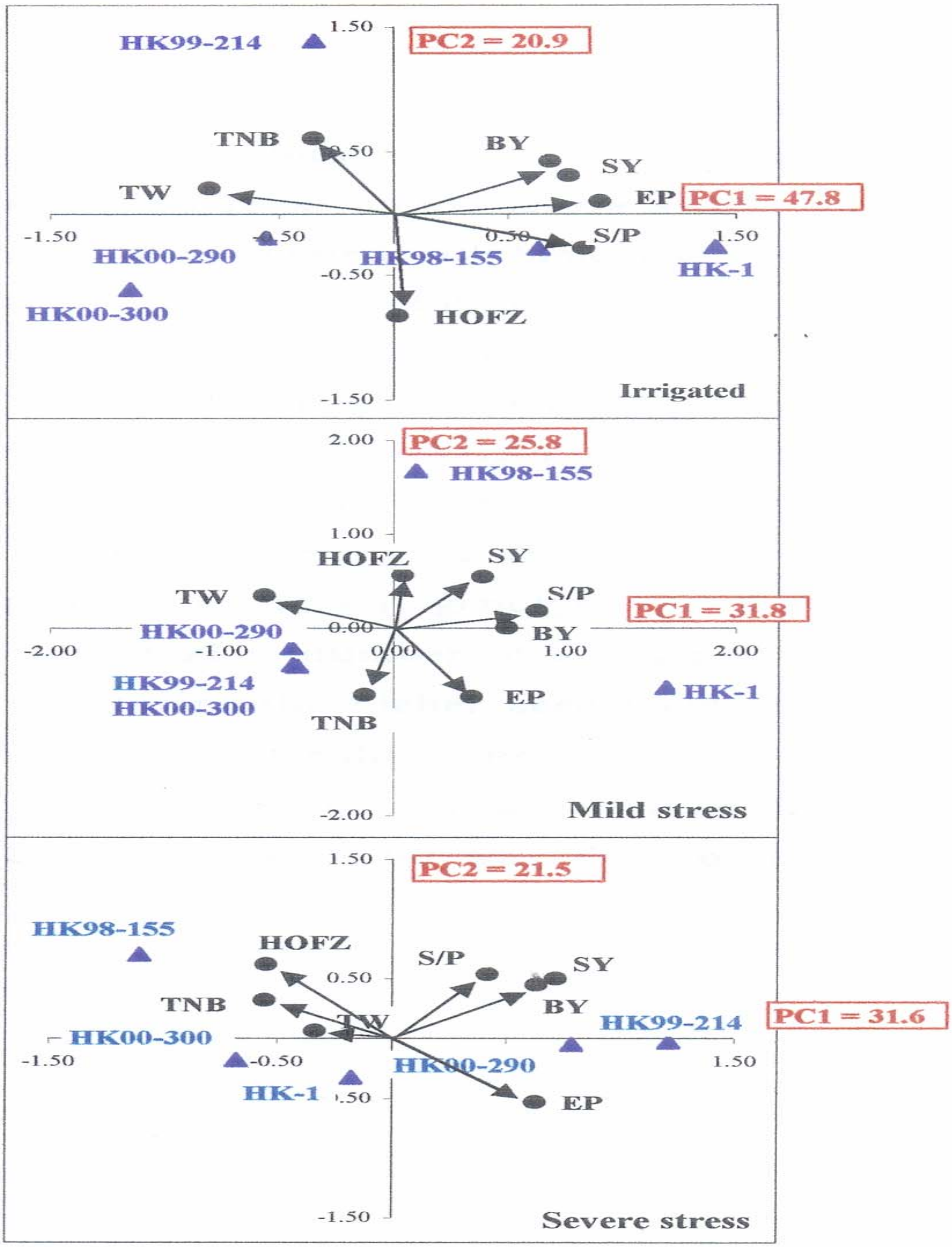

Fig 1. Biplot of chickpea grown under different moisture stress environments.

Table 2. Factor loadings from principle component analysis of chickpea under irrigated mild and severe stress conditions

	PC1	PC2	PC3	PC4	PC5	PC6	PC7
			Severe Stress				
HOFZ	-0.55	0.62	0.04	0.29	-0.06	0.07	0.07
TNB	-0.56	0.32	-0.54	-0.33	0.38	-0.14	0.16
EP	0.63	-0.53	-0.13	0.20	0.39	0.30	0.15
S/P	0.42	0.54	-0.17	0.62	0.20	-0.24	-0.14
SY	0.72	0.50	0.22	-0.14	-0.15	-0.09	0.37
BY	0.63	0.45	0.01	-0.51	0.14	0.21	-0.27
100 SW	-0.34	0.06	0.86	-0.02	0.38	-0.09	0.00
Variance explained (%)	31.6	21.5	16.0	12.9	7.41	6.52	4.06
Cumulative Variance explained (%)	31.6	53.1	69.1	82.0	89.4	95.9	1.00
			Mild stress				
HOFZ	0.06	0.56	0.39	0.70	0.12	0.03	-0.15
TNB	-0.17	-0.71	0.59	0.18	-0.06	-0.28	0.08
EP	0.46	-0.73	0.10	0.10	0.40	0.27	0.01
S/P	0.84	0.18	-0.11	0.36	-0.23	0.02	0.25
SY	0.52	0.54	0.24	-0.40	0.42	-0.19	0.07
BY	0.66	0.01	0.52	-0.37	-0.35	0.13	-0.13
100 SW	-0.75	0.34	0.46	-0.13	0.00	0.24	0.20
Variance explained (%)	31.8	25.8	15.0	14.0	7.60	3.69	2.18
Cumulative Variance explained (%)	31.8	57.6	72.6	86.5	94.1	97.8	1.00
			Irrigated control				
HOFZ	0.02	-0.83	0.43	0.20	0.30	0.01	0.03
TNB	-0.35	0.61	0.68	0.19	-0.14	0.03	0.06
EP	0.90	0.10	-0.10	0.17	0.01	-0.21	0.29
S/P	0.84	-0.28	0.05	0.01	-0.30	0.36	0.05
SY	0.77	0.31	-0.07	0.50	0.12	0.01	-0.22
BY	0.69	0.43	0.12	-0.39	0.40	0.14	0.02
100 SW	-0.80	0.21	-0.30	0.30	0.21	0.26	0.16
Variance explained (%)	47.8	20.9	11.1	8.39	5.91	3.66	2.34
Cumulative Variance explained (%)	47.8	68.6	79.7	88.1	94.0	97.7	100

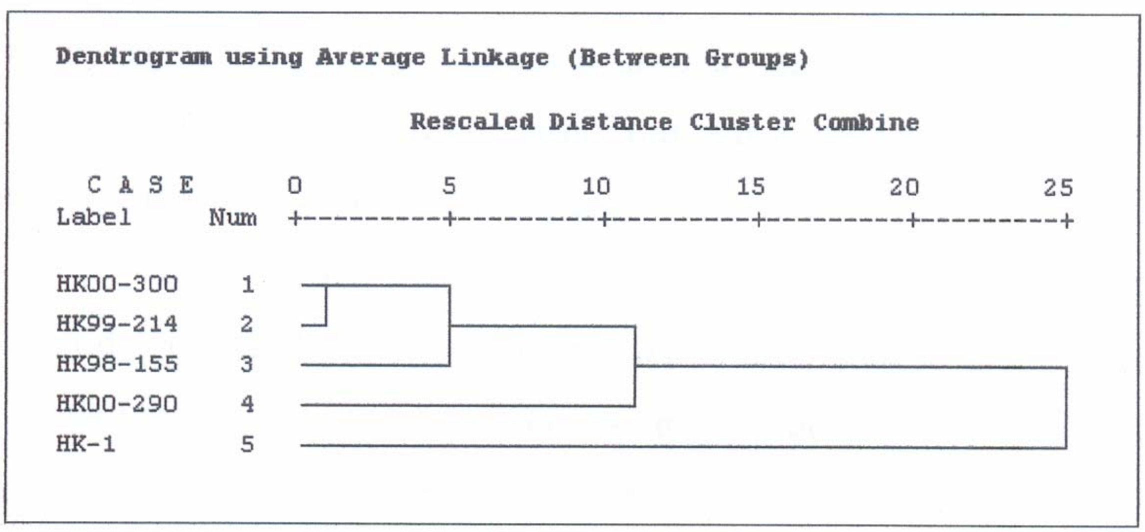

Fig. 2. Relationship among chickpea genotypes grown under different environment.

Hierarchical cluster analysis

The Hierarchical cluster analysis indicates that there is a very little variation in genetic constitution of total genotypes (Fig.2). As the genetic distance in the dendogram representing different genotypes is very little. This shows that these genotypes were bred with either one or both the common parents. The dendogram to show the genetic variability in Fig 2 indicate that the genotype HK00-300 and HK99-214 seems to be the selection from the single cross and HK98-155 has one parent common with them. Similarly, HK00-290 is closely related with HK98-155 and HK1. Although the genetic distance between these genotypes increased in the order HK00-300, HK99-214, HK98-155, HK00-290 and KH-1. This may be due to selection made during different generations of the cross. Findings of Lakshmi Annapurna *et al* (2009) and Leport *et al* (1999) also corroborate these results.

It can be concluded that genotype HK 98-155 holds good promise to perform better under all the tested environments than other genotypes.

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Assessment of improved technologies on chickpea in south-western Haryana

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ABSTRACT

Frontline demonstrations on chickpea crop were consecutively conducted at farmers' fields during 2006-07 to 2010-11 in different districts of south-western regcon of Haryana. Average of 28 frontline demonstrations in five years resulted in 35% higher seed yield of chickpea over farmers' practices. An extension gap of 276 kg/ha between Package of Practices and farmers' practices was recorded. The higher technology gap (949 kg/ha) and technology index (47%) on an average basis reflected the unavailability of adequate Package of Practices to attain its potential yield. The average additional expenditure of Rs. 2222/ha gave higher additional net returns of Rs. 6288/ha in demonstrations. The incremental benefit-cost ratio ranged between 2.1 to 3.6 averaging 2.9 during the study period. Technical breakthroughs, efficient extension network and market stability are required to attain the potentials.

Key words : Chickpea, front line demonstrations, extension gap, technology gap, market stability

INTRODUCTION

Chickpea has got its own importance among *rabi* pulse crops grown in south-western Haryana. During the year 1999-2000, the total cultivated area under this crop was 0.1 m.ha and now it has increased to 0.112 m.ha (Anonymous, 2011-12). Its productivity has also increased from 577 kg/ha to 982 kg/ha during the corresponding period. The reasons for increasing trend in area and its productivity may be attributed to the use of improved seeds, better agronomic practices, adequate plant protection measures and price stability. Frontline demonstrations programme was initiated a decade back to demonstrate the production potential, benefits of Package of Practices vis-à-vis traditional farmers' practices in Sirsa, Fatehabad, Hisar and Bhiwani districts of south-western region of Haryana.

MATERIALS AND METHODS

Frontline demonstrations (FLDs) were laid out in *rabi* season during 2006-07 to 2010-11 at farmers' fields to find out the economic viability of technologies transfer and adoption in chickpea in Sirsa, Fatehabad, Hisar and Bhiwani districts of south-western region of Haryana state. The soils of different sites were loamy sand to sandy loam in texture with pH ranging from 7.6 to 8.0. The soils were low in organic carbon and available nitrogen, low to medium in available phosphorus and medium to high in available potash. The entire quantity of fertilizer i.e. 20 kg N and 40 kg P_2O_5/ha was drilled at the time of sowing. Sowing was done in the second fortnight of October using 40 kg seed/ha of variety HC-5. Improved package of practices were applied in the demonstrations for raising chickpea crop. To show the worth of the demonstrations, the traditional farmers' practices were compared and various gaps were calculated using weighted means of demonstrations. The following formulae suggested by Prasad *et al.* (1993) were used to find out the gaps and index :

(a) Extension gap (kg/ha)= Demonstration yield (Di) – Farmers' yield (Fi)

(b) Technology gap (kg/ha) = Potential yield (Pi) – Demonstration yield (Di)

(c) $$\text{Technology index} = \frac{(\text{Pi}-\text{Di}) \times 100}{\text{Pi}}$$

(d) Additional return (Rs./ha) = (Di – Fi) x Sale price

(e) Effective gain (Rs./ha) = Additional returns – Additional cost

(f) $$\text{Incremental Benefit Cost ratio (IBCR)} = \frac{\text{Additional returns}}{\text{Additional cost of inputs}}$$

RESULTS AND DISCUSSION

Seed Yield

The package of demonstrated technology improved the seed yield of chickpea ranging from 28 to 45% over farmers' practices and on an average, 35%

higher seed yield was recorded under frontline demonstrations as compared to traditional farmers' practices (Table 1). Enhanced seed yield might be due to adoption of improved technology in the form of recommended package of practices. Similar results have been reported by Yadav *et al.* (2004).

Extension Gap

Wide extension gap observed as a measure of seed yield difference between improved practices and farmers' practices was recorded during all the years of study. On an average of 28 demonstrations, the extension gap was recorded as 276 kg/ha. This gap could be attributed to poor adoption of farming practices like timely sowing, crop geometry, poor plant population, imbalanced use of fertilizers, lack of weed control, non adoption of integrated nutrient management and inadequate plant protection measures under traditional farming practices. Such gap revealed about the essence of improved Package of Practices adopted in frontline demonstrations. Lower extension gap led to good extension activities which resulted in significantly high adoption of improved technology by the farmers. The gap can be lowered down further by strengthening extension activities (Siag *et al.*, 2000).

Technology Gap and Index

FLDs were conducted under the supervision of scientists; however, there was still a wide gap between crop's potential yield and FLD yield. This was mainly due to weather conditions, variation in soil fertility, location specific management problems and poor irrigation facilities in a few demonstrations. This gap could be bridged up only by adoption of location specific recommendations (Kadian *et al.*, 1997). The technology gap ranged from 710 to 1130 kg/ha during various years and on an average basis of five years, it was 949 kg/ha (Table 1). There was inverse relationship between technology gap and extension gap. The higher technology gap showed worth of existing technologies in real farming situation (Yadav *et al.*, 2004). The technology index is the significance of evolved technology feasible at farmers' fields. Low value of technology index, as a function of technology gap, indicated the higher perfection of technology. The technology index was the highest (56%) during the year 2007-08 and the lowest (35%) during the year 2008-09 and the average 47% in accordance with the technology gap. The higher technology gap index might be due to inadequate package of research findings which could perform as per potential in different agro-climatic conditions. The technology index could be lowered down in real sense by evolving location specific research innovations to bridge the gap between the potential yield and demonstrations improved practices yield (Kadian *et al.*, 1997).

Table 1. Seed yield and gap analysis of frontline demonstrations on chickpea

Year	No. of demonstrations	Seed yield (kg/ha)			Increase in seed yield over farmers practices (%)	Extension gap (kg/ha)	Technology gap (kg/ha)	Technology index (%)
		Potential	Improved practices	Farmers' practices				
2006-07	9	2000	1090	750	45	340	910	45
2007-08	2	2000	870	680	28	190	1130	56
2008-09	9	2000	1290	950	36	340	710	35
2009-10	3	2000	1030	760	35	270	970	48
2010-11	5	2000	976	738	32	238	1024	51
	Total : 28	Av. 2000	1051	776	35	276	949	47

Economic Analysis

The seed yield variations and sale price of chickpea during different years influenced the total returns. On an average, incurring of Rs. 2222/ha resulted into an additional benefit of Rs. 6288/ha than farmers' practices (Table 2). The highest effective gain of Rs. 5400/ha was recorded with an average of Rs. 4066/ha. IBCR ranged from 2.1 to 3.6. On an average, IBCR of 2.9 was recorded during the study period. It means that by incurring one more rupee on improved practices, the farmer will get a benefit of Rs. 2.9. The results of this

Table 2. Economic evaluation of frontline demonstrations on chickpea

Year	Cost of cultivation (Rs./ha)		Total returns (Rs./ha)		Additional cost in demonstrations (Rs./ha)	Additional returns in demonstrations (Rs./ha)	Effective gain (Rs./ha)	Incremental benefit-cost ratio (IBCR)
	practices	practices	practices	practices				
2006-07	15620	13 540	23980	16500	2080	7480	5400	3.6
2007-08	14570	12380	20880	16320	2190	4560	2370	2.1
2008-09	14750	12560	28380	20900	2190	7480	5290	3.4
2009-10	13890	11640	23690	17480	2250	6210	3960	2.8
2010-11	13920	11520	23424	17712	2400	5712	3312	2.4
Average	14550	12328	24071	17782	2222	6288	4066	2.9

study are in line with the findings obtained by Yadav *et al.* (2004) and Sidhu *et al.* (2003).

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Evaluation of some herbicides against *Asphodelus tenuifolius* Cav.

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ABSTRACT

Asphodelus tenuifolius is a major weed of mustard and chickpea in India, though it also infests many other crops across several continents. Pre-emergence application of dinitroanilines in oilseed and pulse crops is not effective against *A. tenuifolius* and requires more than one mechanical weeding for its effective control. Mechanical weeding is not only costly; labour is not available at critical periods for weeding. Pot studies were conducted to evaluate the efficacy of naproanilide (0.5 to 4.0 kg ai/ha), clopyralid (0.125 to 0.50 kg ai/ha), bentazon and isoproturon (0.25 to 2. 0 kg ai/ha) applied post-emergence to *A. tenuifolius*, grown in pots in the screen house at CCS Haryana Agricultural University, Hisar. Naproanilide and clopyralid were less effective in reducing the dry weight of *A. tenuifolius* and failed to provide its satisfactory control. The reduction in dry weight of *A. tenuifolius* by 0.5 kg/ha of clopyralid and 4.0 kg/ha of naproanilide (highest use rates) was only 46 and 55%, respectively over untreated control compared to 72 and 91% reduction by isoproturon and bentazon at 2.0 kg/ha, respectively. Probit analysis of visual mortality data revealed the GR_{50} values of naproanilide, clopyralid, bentazon and isoproturon as 3.39, 0.71, 0.086 and 0.75 kg ai/ha, respectively. Higher dose of isoproturon required to effectively control *A. ludoviciana* applied post-emergence may not be safe for mustard crop. Field studies are required to verify the results of pot studies for the efficacy of bentazon against *A. tenuifolius* and other infesting weeds in pulse crops.

Key words : Crop selectivity and rotations, herbicide efficacy, probit analysis, yield reduction

INTERODUCTION

Asphodelus tenuifolius Cav. (Piazi) is an erect, annual, monocotyledonous herb of Liliaceae family with yellowish (young plant) and dark brown (at maturity) deep roots to extract moisture from deeper soil layers. It is a serious weed of mustard, chickpea, wheat, lentil, linseed and other winter season crops in India. Holm *et al.* (1997) reported *A. tenuifolius* as a serious weed of 15 crops in 17 countries. Other than India and Pakistan, it has become a serious weed in some regions of Australia, Spain, USA and New Zealand. Mustard and chickpea are the major crops of arid and semi-arid regions where *A. tenuifolius* is the most dominant weed. A survey conducted in Haryana State revealed that *Chenopodium album* was present in 92% fields with relative intensity of 1.41 (0-10 scale) in four major chickpea producing districts, whereas *A. tenuifolius* was present in 97.5% fields with a relative intensity of 1.95 (Malik and Singh, 1994). It infested 76% mustard fields (average of six districts) with a mean relative intensity of 1.78 compared to 83% occurrence by *C. album* and mean intensity of 1.42. *A. tenuifolius* intensity and occurrence in chickpea was higher in Sierozem soil (2.5 and 100%) compared to Desert soil (1.75 and 92%, respectively). However, in case of mustard its intensity and occurrence was more in Desert soil (1.81 and 92%) compared to Sierozem soil (1.70 and 80%, respectively) which may be due to variations in soil fertility, moisture level and competition from mustard crop. Mishra *et al*. (2006) observed that wheat, pea, and mustard were the most competitive crops against *A. tenuifolius*. Singh *et al*. (1995) found greater occurrence of *A. tenuifolius* in light than heavy soils in wheat fields and it was conspicuous by its absence in the north-eastern parts of Haryana where rice-wheat copping system is more common. Under rainfed or limited resource conditions, it competes vigorously reducing the yield by 56% in mustard (Yaduraju *et al*., 2000) and 30-54% in chickpea (Mukherjee, 2007). Under heavy infestation, yield losses up to 80% have been reported (Tewari *et al*. 2001). Yadav and Poonia (2005) reported that low productivity of mustard in Rajasthan was due to heavy infestation of *A. tenuifolius*. Not only it competes vigorously with crops, it also has allelopathic potential to suppress the germination and growth of wheat, mustard, chickpea, and lentil (Mishra *et al.,* 2002; Babar *et. al*. 2009). Early planting of mustard and chickpea also helps in increased infestation of *A. tenuifolius* compared to late planting of mid-November as its germination was found more under higher temperature of October than in November (Sahai and Bhan, 1991). Its dormancy under unfavourable conditions also helps in its survival as a successful weed of mustard and chickpea. Mechanical weeding is not successful due to its quick regeneration and high cost of weed control. Dinitroaniline herbicides (fluchloralin, trifluralin and pendimethalin) are used in mustard and chickpea, but are not effective against *A. tenuifolius* (Yadav and Poonia, 2005) and need one mechanical weeding for its effective control. Tewari *et al*., (2001) reported that initial 60 days period was critical for weed competition in rainfed chickpea dominated with *A. tenuifolius*. Mechanical weeding by manual labour is not only difficult, but is not always available at critical crop-weed competition periods. There are no selective and effective post-emergence herbicides for managing *A. tenuifolius* in pulses and oilseed crops in India, though it can effectively be controlled in wheat using 2,4-D alone or its mixture with isoproturon (Poonia *et al*., 2001) and metsulfuron. Under these conditions, four herbicides were evaluated in pots to assess their efficacy against *A. tenuifolius*.

MATERIALS AND METHODS

A pot culture study was conducted in the screen house of CCS Haryana Agriculture University, Hisar in the winter season using earthen pots of 30 cm height and top diameter. Field soil of sandy loam texture (62% sand, 23% silt, 14% clay, with 0.4% organic matter and a pH of 8.2) was used as a potting mixture after passing through 2 mm sieve and mixing with well rotten FYM in 5:1 ratio. Twenty seed of *A. tenuifolius,* collected from infested fields were planting in pots. Thinning was performed after emergence and ten plants per pot were maintained for spraying. Four herbicides *viz*., **naproanilide** (50% DF) [2-(2-Naphthyloxy)-N-phenylpropanamide] a selective herbicide that controls annual and perennial broad-leaved weeds and sedges was applied at 0, 0.5, 1.0, 2.0 and 4.0 kg ai/ha; **clopyralid** (30% SL) (3,6-dichloro-2-pyridinecarboxylic acid) a selective herbicide for broadleaf weeds was applied at 0, 0.125,0.25, 0.375 and 0.50 kg ai/ha; **bentazon** (48% SL) (3-Isopropyl-1*H*-2,1,3-benzothiadiazin-4(3*H*)-one 2,2-dioxide) a selective post emergence (POST) herbicide for selective control of broadleaf weed and sedges in rice, corn, sorghum, soybeans, peanuts, alfalfa, beans (with the exception of garbanzo beans), peas (with the exception of blackeyed peas), pepper, peppermint, spearmint, lawns and turf was applied at 0, 0.25,0.50, 1.0 and 2.0 kg ai/ha; **isoproturon** (75% WP) (3-(4-isopropylphenyl)-1,1-dimethylurea) a selective, systemic herbicide for the control of annual grasses and broad-leaved weeds was applied at 0, 0.25,0.50, 1.0 and 2.0 kg ai/ha. Herbicides were sprayed by a knapsack sprayer fitted with flat fan nozzle delivering 500 l water at 30 psi pressure. There were three replicated pots for each herbicide and dose along with control plots arranged in a CRD design. Plants were watered as per need. Observations were recorded on mortality at 2 and 3 weeks after treatment (WAT). Experiment was terminated 4 WAT after recording dry weight of plants. Experiment was repeated and pooled data was subjected to ANOVA using SPSS. Percent mortality data was used for Probit analysis to find out GR_{50} (growth reduction by 50%) value for different herbicides.

RESULTS AND DISCUSSION

Visual mortality

Naproanilide and clopyralid failed to provide satisfactory control of *A. tenuifolius* as their highest dose rate of 4.0 and 0.5 kg/ha provided only 45 and 40% % mortality, respectively (Fig. 1 and 2). Though, *A. tenuifolius* mortality increased with increasing dose of naproanilide, but its 2.0 kg/ha dose could inflict only 18% mortality requiring a higher GR_{50} dose of 3.39 kg/ha. Similarly, clopyralid 0.375 kg/ha provided only 22% mortality which was significantly lower than its higher dose of 0.50 kg/ha and required 0.71 kg/ha for 50% mortality (GR_{50}). Bentazon was most effective as it was able to provide 73% mortality at the lowest use rate of 0.25 kg/ha and complete mortality at 2.0 kg/ha (Fig. 3). Bentazon 1.0 kg provided 90% mortality of *A. tenuifolius* that was statistically similar to its 2.0 (100%) or 0.5 kg/ha (82%) dose. The GR_{50} value of bentazon was calculated only 86 g/ha making the most effective among the test herbicides. Isoproturon 0.50 kg/ha provided 43% mortality, increasing the dose rate to 1.0 and 2. 0 kg/ha significantly increased the mortality of *A. tenuifolius* to 60 and 73%, respectively (Fig. 4). *A. tenuifolius* required 0.75 kg/ha of isoproturon for 50% mortality.

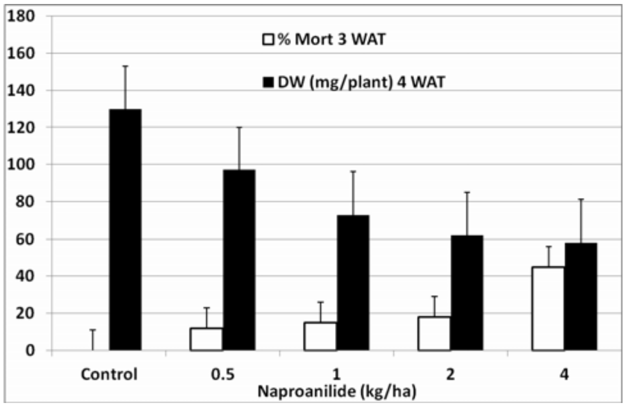

Fig. 1. Effect of naproanilide on mortality and dry matter accumulation by *A. tenuifolius* (error bars represent C. D. at 5%)

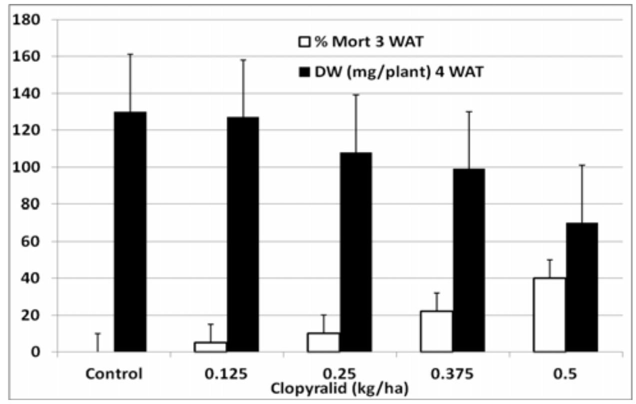

Fig. 2. Effect of clopyralid on mortality and dry matter accumulation by *A. tenuifolius* (error bars represent CD at 5%)

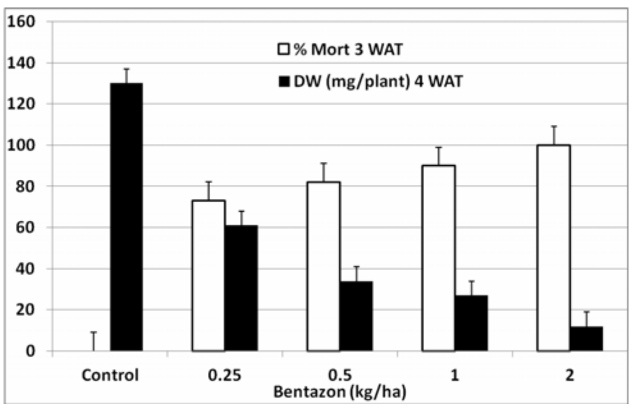

Fig. 3. Effect of bentazon on mortality and dry matter accumulation by *A. tenuifolius* (error bars represent CD at 5%)

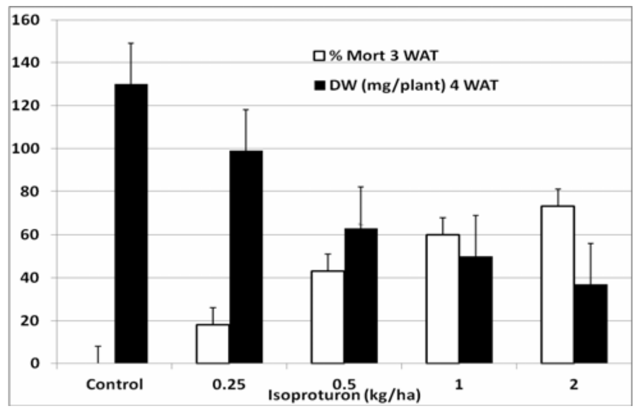

Fig. 4. Effect of isoproturon on mortality and dry matter accumulation by *A. tenuifolius* (error bars represent CD at 5%)

Effect on Dry weight

Naproanilide 0.5 kg/ha reduced the dry weight of *A. tenuifolius* by 25% compared to untreated control (Fig. 1). Increasing the dose of naproanilide from 0.5 to 4.0 kg/ha reduced the dry matter accumulation of *A. tenuifolius* by 44, 52 and 55% over control plants. The reduction in dry weight of *A. tenuifolius* was lower with clopyralid (Fig. 2). The highest dose of clopyralid (0.5 kg/ha) could only reduce the dry weight of *A. tenuifolius* plants by 45% compared to 53% by 0.25 kg/ha of bentazon (Fig. 3). Increasing the dose of bentazon from 0.5 to 1.0 and 2.0 kg/ha significantly reduced the dry weight of *A. tenuifolius* by 73, 79 and 91%, respectively over unsprayed plants. Lower rates of isoproturon were less effective, but its highest dose of 2.0 kg/ha lowered the dry weight of *A. tenuifolius* by 72% (Fig. 4).

Yaduraju *et al*. (2000) found that under pot conditions, pre-emergence (PRE) application of isoproturon was least effective compared to other herbicides. Similarly, they found that PRE application of isoproturon, pendimethalin and oxyfluorfen failed to reduce *A. tenuifolius* infestation in mustard under field conditions. Yadav *et al*., (1999) reported that PPI and PRE application of isoproturon 0.75 kg/ha reduced the population of *A. tenuifolius* by 91 and 86% (mean of two years), respectively over control during 1995-96 and 1996-97 field trials. The yield increase by 0.75 kg/ha of isoproturon applied PPI and PRE increased mustard yield by 122 and 106%, respectively over control. They found that PPI application of isoproturon 0.75 kg was similar to two hand weeding and better than pendimethalin 1.0 kg PRE and fluchloralin 1.0 kg/ha PPI in reducing weed population, their dry matter accumulation and increasing crop yield. Under the present study isoproturon required a GR_{50} value of 0.75 kg/ha, which is normally used for the control of weeds in mustard (Singh *et al*., 1992). Increasing the dose of isoproturon to 1.0 kg/ha with POST application resulted in crop injury and lowered yield than 0.75 kg/ha rate. So, there could be lower control of *A. tenuifolius* with 0.75 kg/ha rate of isoproturon when applied POST. PPI or PRE application is less desired by farmers because of moisture constraint under reinfed conditions and there is always a preference for POST application, if there is a selective and effective herbicide. Isoproturon is not safe for chickpea and is not suitable for the control of *A. tenuifolius* when applied POST.

Naproanlide and clopyralid failed to satisfactorily control *A. tenuifolius* even at the highest use rates. Bentazon, a broad-spectrum herbicide has been found effective in soybean and other crops for the control of annual broadleaf weeds and sedges without any adverse effect on pulses/beans (Singh-Verma and Liub, 1974; Van Gessel *et al*., 2000). Being a contact herbicide, some transient crop injury may appear due to weather conditions, but has no bearing on crop yield. Efficacy enhancement of bentazon has been observed with surfactant and it can be tank mixed with other herbicides for better control of sedges (Armel *et. al*., 2008). Crop rotation of chickpea and mustard with wheat is not always feasible in the north-western parts of India, where *A. tenuifolius* can be controlled by selective herbicides. Since there is no post-emergence selective herbicide for pulses to effectively control *A. tenuifolius;* bentazon was found highly effective against *A. tenuifolius* under control conditions and its field evaluation is required to confirm the results of pot studies.

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Efficacy of some ACCase and ALS inhibitor herbicides and their combinations against weeds in wheat (*Triticum aestivum* L.)

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ABSTRACT

Repeated use of broad-spectrum herbicide, isoproturon led to evolution of resistance in *Phalaris minor*. Isoprpoturon substitution with clodinafop and fenoxaprop resulted in shift of weed flora towards dominance of broadleaf weeds. For effective control of grassy and broadleaf weeds, tank mix application of grassy and broadleaf herbicides or their sequential application is required to harvest good crop of wheat. In the present study tank mix of clodinafop + metsulfuron-methyl (10:1) at 50 or 60 g a.i/ha provided efficient control of complex weed flora resulting in higher values of growth parameters, yield attributes and yield of wheat. Fenoxaprop and clodinafop were effective only against grassy weeds whereas sulfosulfuron controlled both grassy and broad leaved weeds.

Key words : Herbicide mixture, *Phalaris minor*, weed control efficiency

INRODUCTION

Continuous use of same herbicide or herbicides with similar mode of action in monoculture generally causes shift in weed flora and development of resistance in weeds. The first such case of herbicide resistance in India was reported in *Phalaris minor* against isoproturon in Haryana, particularly in areas where rice-wheat cropping system was continuously followed for 10-15 years (Malik and Singh, 1993; Singh *et al*., 1997). Herbicide resistance resulted in very poor to no control of *P. minor* and consequently heavy losses to total crop failure at many locations (Malik and Singh, 1995; Singh *et al*., 1999).

Therefore, it was imperative to look for new alternative herbicides with different mode of action, and improved efficacy against *P. minor* and selectivity for wheat (Singh, 2007). Hence, the present study was undertaken to assess the bioefficacy of clodinafop and various herbicide mixtures for weed control in wheat (*Triticum aestivum* L.).

MATERIALS AND METHODS

A field experiment was conducted in wheat during *rabi* of 2002-03 and 2003-04 on sandy loam soil, low in available N (205 kg/ha), medium in available P (15.20 kg/ha) and high in available K (401 kg/ha) with slightly alkaline in reaction (pH 8.1) at Research Farm, Department of Agronomy, CCS Haryana Agricultural University, Hisar. Wheat variety PBW-343 at seed rate of 100 kg/ha was sown under furrow irrigated raised bed system on November 12 and 14 during 2002-03 and 2003-04, respectively. Seventeen treatments consisting of two formulations of clodinafop-propagyl (15WP and 10 EC) at various doses (alone and tank mix with metribuzin), fenoxaprop, sulfosulfuron and metribuzin. The treatments laid out in a plot size of 7.0 x 2.1 m in randomized block design with three replications. The herbicides were sprayed as per treatment at 35 days after sowing (DAS) with the help of knap sack sprayer fitted with flat fan nozzle using 625 liter water/ha. Crop was raised according to package of practices of CCSHAU, Hisar. Observations were recorded for weed density of grassy and broadleaf weeds infesting the treated plots and their dry matter accumulation using a quadrat of 0.5 x 0.5 m. Yield attributes of wheat and yield was recorded at harvest. Data was subjected to analysis of variance for individual years.

RESULTS AND DISCUSSION

Effect on weeds

The dominant weed flora in the experimental field comprised of *Phalaris minor* Retz. *Avena ludoviciana* Dur., *Chenopodium album L.* and *Convolvulus arvensis L.* during both the years. Remaining weed species grouped under miscellaneous weeds comprised of *Melilotus indica (L.) All.*,

Table 1. Effect of different weed control treatments on weed density (No. m^{-2}) and total weed dry weight (g m^{-2}) at 60 days after seeding wheat

Treatments	Dose (g a. i. /ha)	*Weed density (number/*m^2								Total weed dry weight (g/m^2)	
		P. minor		*A. ludoviciana*		*C. album*		*C. arvensis*			
		2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
Fenoxaprop	120	1.41 (1.0)	1.51 (1.3)	1.73 (2.0)	1.71 (2.0)	5.19 (26.0)	5.81 (33.0)	2.22 (4.0)	2.62 (6.0)	12.6	20.0
Sulfosulfuron	25	1.41 (1.0)	1.41 (1.0)	1.99 (3.0)	1.73 (2.0)	3.44 (11.0)	3.34 (10.0)	1.73 (2.0)	2.00 (3.0)	5.8	6.7
Clodinafop 15WP	50	1.71 (2.0)	1.61 (1.5)	1.64 (1.7)	1.67 (1.8)	4.79 (22.0)	5.72 (32.0)	2.22 (4.0)	2.84 (7.0)	16.2	22.0
Clodinafop 15WP	60	1.73 (2.0)	1.51 (1.3)	1.57 (1.5)	1.57 (1.5)	4.81 (23.0)	5.70 (31.3)	2.42 (5.0)	2.62 (6.0)	14.8	20.2
Clodinafop 10EC	50	1.73 (2.0)	1.67 (1.8)	1.73 (2.0)	1.71 (2.0)	4.68 (21.3)	5.50 (29.0)	2.22 (4.0)	2.98 (8.0)	13.3	22.7
Clodinafop 10EC	60	1.57 (1.5)	1.61 (1.6)	1.67 (1.8)	1.54 (1.4)	4.99 (24.0)	5.57 (30.3)	2.44 (5.0)	2.98 (8.0)	15.4	20.7
Metribuzin	250	2.86 (7.0)	2.48 (5.3)	2.74 (6.6)	2.54 (5.4)	1.61 (1.5)	1.64 (1.8)	1.73 (2.0)	1.71 (2.0)	4.1	6.0
Metribuzin	300	2.61 (6.0)	2.22 (4.0)	2.89 (7.3)	2.46 (5.0)	1.41 (1.0)	1.41 (1.0)	1.41 (1.0)	1.63 (1.8)	4.0	5.9
Clodinafop 15WP+ MSM (1:5)	250	2.00 (3.0)	1.71 (2.0)	2.00 (3.0)	1.82 (2.5)	2.22 (4.0)	2.46 (5.0)	1.99 (3.0)	1.99 (3.0)	2.2	3.0
Clodinafop 15WP+ MSM (1:5)	300	1.73 (2.0)	1.61 (1.5)	1.73 (2.0)	1.54 (1.5)	2.04 (3.3)	2.14 (3.5)	2.00 (3.0)	1.89 (2.5)	1.8	2.5
Clodinafop 10EC+ MSM (1:4)	250	1.71 (2.0)	1.73 (2.0)	1.84 (2.4)	1.64 (1.8)	1.99 (3.0)	2.0 (3.0)	1.99 (3.0)	1.84 (2.5)	1.6	2.7
Clodinafop 10EC+ MSM (1:4)	300	1.62 (1.6)	1.57 (1.5)	1.81 (2.3)	1.51 (1.3)	1.72 (2.1)	1.71 (2.0)	1.78 (2.1)	1.73 (2.0)	1.8	2.4
Clodinafop 10EC+ MSM (1:5)	250	2.00 (3.0)	1.64 (1.8)	2.00 (3.0)	1.89 (2.6)	2.30(4.2)	2.34 (4.5)	1.99 (3.0)	2.06 (3.3)	2.6	3.0
Clodinafop 10EC+ MSM (10:1)	50	1.81 (2.3)	1.73 (2.0)	1.86 (2.5)	1.73 (2.0)	2.22(4.0)	2.32 (4.3)	1.73 (2.0)	2.00 (3.0)	3.0	2.8
Clodinafop 10EC+ MSM (10:1)	60	1.73 (2.0)	1.78 (2.1)	1.73 (2.0)	1.57 (1.5)	1.99 (3.0)	2.14 (3.5)	1.73 (2.0)	1.73 (2.0)	2.4	2.3
Weedy check		5.56 (30.0)	5.38 (28.0)	6.63 (43.0)	5.72 (32.0)	5.19 (26.0)	5.81 (33.0)	2.42 (5.0)	2.98 (8.0)	22.8	28.8
Weed free		1.00 (0.0)	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)	0.0	0.0
CD at 5%		0.26	0.39	0.49	0.39	0.53	0.72	0.35	0.38	3.0	2.6

Original data given in parentheses was subjected to square root (x+1) transformation before analysis, MSM=metsulfuron-methyl

Table 2. Effect of weed control treatments on yield attributes, grain and straw yields of wheat at harvest

Treatments	Dose (g a. i. /ha)	Grain/spike		Spike length (cm)		Effective tillers (No./m)		Grain yield (kg/ha)		Straw yield (kg/ha)	
		2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
Fenoxaprop	120	50.0	51.3	10.1	10.1	95	96	5138	5150	6422	6389
Sulfosulfuron	25	51.4	52.4	9.8	10.0	97	100	5338	5389	6669	6610
Clodinafop 15WP	50	51.2	51.7	9.9	9.8	96	97	5164	5230	6358	6417
Clodinafop 15WP	60	52.1	52.5	9.9	10.3	95	98	5172	5286	6372	6431
Clodinafop 10EC	50	51.0	52.0	9.8	9.9	96	97	5035	5281	6296	6442
Clodinafop 10EC	60	52.3	52.8	9.7	9.8	96	97	5168	5196	6367	6383
Metribuzin	250	51.4	51.8	9.8	9.6	93	92	5065	5099	6172	6214
Metribuzin	300	49.0	49.2	9.6	9.7	91	91	4894	4863	6068	6181
Clodinafop 15WP+MSM (1:5)	250	49.3	49.0	9.7	9.5	95	95	5093	5011	6212	6236
Clodinafop 15WP+MSM (1:5)	300	49.1	48.7	9.7	9.6	94	95	5072	5074	6238	6241
Clodinafop 10EC+MSM(1:4)	250	50.0	49.5	9.8	9.6	93	94	4936	5056	6130	6453
Clodinafop 10EC+MSM (1:4)	300	49.7	49.3	9.5	9.5	92	93	4902	4928	6167	6207
Clodinafop 10EC+MSM (1:5)	250	49.2	49.5	9.7	9.8	95	96	5079	5066	6239	6267
Clodinafop 10EC+MSM (10:1)	50	53.0	53.5	10.2	10.4	101	100	5587	5629	6877	6893
Clodinafop 10EC+MSM (10:1)	60	53.8	54.6	10.5	10.4	101	101	5595	5648	6868	6910
Weedy check		47.2	48.1	9.1	9.0	83	86	3439	3142	4505	4361
Weed free		55.2	56.7	10.6	10.9	103	104	5828	5806	7132	7136
CD at 5%		2.3	2.5	0.2	0.3	3.1	3.5	311	342	339	381

MSM = metsulfuron-methyl

Coronopus didymus (L.) Sm., *Anagallis arvensis L., Lathyrus aphaca L.* and *Rumex dentatus* L.

All the herbicidal treatments significantly reduced the density and dry weight of weeds over weedy check (Table 1). However, clodinafop (EC or WP) and fenoxaprop were not able to control broad-leaved weeds whose density and dry matter was found to be at par with that recorded under weedy check plots. These results are in conformity with Dhaliwal *et al.* (1998).

Application of metribuzin alone, controlled grassy weeds but the control obtained was statistically lower than by other treatments. While sulfosulfuron effectively controlled the complex weed flora in wheat as also observed by Banga *et al.* (2003) and Singh *et al*. (2003). Metribuzin applied alone or as tank mixture with clodinafop significantly reduced the density and dry matter of total weeds during both the years. These findings are in conformity with Singh *et al*. (2001) and Yadav *et al*. (2004).

Tank mixture of clodinafop 10 EC with metsulfuron-methyl (50 or 60 g/ha) in 10:1 ratio provided the most efficient weed control due to control of broad spectrum of weed flora and significant reduction in their dry matter.

Effect on Crop

Highest values of yield attributes and wheat grain yield was recorded with weed free plots while the lowest values were recorded in weedy check. Clodinafop 10 EC + metsulfuron (10:1) at 50 or 60 g/ha resulted in statistically higher yield attributes, straw and grain yield which was in par with weed free in both the years (Table: 2). This might be due to efficient control of weeds as observed in this study.

Metribuzin (250 and 300 g/ha) or tank mix application of metribuzin with clodinafop (WP or EC) significantly reduced the yield attributes, straw and grain yield of wheat in both the years (Table 2). Sharma and Pahuja (2001), Yadav *et al*. (2004) also reported similar results. This might be attributed to phytotoxic effect of metribuzin on wheat as observed by Singh *et al*. (2001) and Yadav *et al*. (2004).

Sulfosulfuron, fenoxaprop and clodinafop (WP or EC) were at par with each other in increasing grain and straw yield of wheat during both the years.

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Periodic soil moisture and ground water use by wheat under shallow water table conditions as influenced by preceding crops, planting methods and moisture regimes

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ABSTRACT

Zero-tillage and conventional sowing practices of wheat were evaluated succeeding mungbean and sorghum under three moisture regimes *viz*., irrigation at CRI + IW/CPE of 0.5, 0.7 and 0.9 during two consecutive *rabi* seasons of 2003-2004 and 2004-05 at the Research Farm of CCS Haryana Agricultural University, Hisar, on a sandy loam soil having basic infiltration rate of 4.2 mm/h, 20.5% and 7.2% moisture at -0.03 MPa and -1.5 MPa. The experiment was laid out in a split plot design with three replications. During 2003-04, soil moisture depletion by wheat was relatively higher succeeding sorghum than mungbean, but the reverse trend was observed during 2004-05. Conventional till wheat resulted in comparatively higher soil moisture depletion during both the crop seasons. During 2003-04 crop season, the soil moisture depletion was higher with irrigation moisture regimes of CRI + IW/CPE=0.5 at all the stages as compared to the higher moisture regimes of irrigation at CRI + IW/CPE=0.9 and 0.7. However, varying moisture regimes did not influence the soil moisture depletion during the early and development stages markedly in second crop season. The ground water flux was substantially higher succeeding mungbean (123 mm) than sorghum (111 mm) for the various crop stages, except the early growing period during 2003-04. In 2004-05, it was significantly higher during sowing to spike initiation and milk to maturity stages. Zero tillage practice in wheat resulted in significantly higher ground water use than conventional tillage during milk to maturity stage as well as for the entire crop period. Higher moisture regimes of irrigation at CRI + IW/CPE=0.9 resulted in lower ground water use than CRI + IW/CPE=0.5 in 2003-04 during spike initiation to anthesis and milk to maturity stages. While in 2004-05, the difference was marked for milk to physiological stage and for the whole crop season.

Key words : Zero-tillage, wheat, preceding crops, mungbean, sorghum, soil moisture depletion, ground water contribution, shallow water table

INTRODUCTION

Wheat is the major cereal of crop of rabi season in North-West India requiring about 30-35 cm of irrigation water. During the crop season, available moisture in the soil and the water table fluctuation under shallow water table conditions plays important role in determining the crop water requirement and hence, deciding irrigation schedule. Zero tillage has been reported as promising technology in terms of savings in fuel, labour, irrigation water, production cost, energy *etc*. along with positive effects on soil health and environmental quality by several workers. Judicious use of water improves the efficiency of other applied inputs leading to increased crop yields and thus enhances the overall water productivity. Zero-tillage has resulted in increased water productivity in wheat by 31.7% (Malik *et al*., 2006).

Several criteria have been used by researchers for scheduling irrigation in wheat to improve the water productivity. Water supplied on IW/CPE basis was more economical and convenient than other criteria. Preceding crop affects the soil moisture availability to the crop by its uptake to meet the evapo-transpiration need. Moreover, the shallow water table also influences the water use by the crop through upward flux. Since, the behaviour of water distribution in the root zone soil and its use by the wheat crop under zero-tillage may be different than that of conventional tillage, the information on soil moisture and ground water use by wheat is needed. Hence, an experiment was conducted to estimate periodic soil moisture and ground water use by wheat under shallow water table conditions as influenced by preceding crops, planting methods and moisture regimes

MATERIALS AND METHODS

Zero-tillage and conventional sowing practices of wheat were evaluated succeeding mungbean and sorghum under three moisture regimes *viz*., irrigation at CRI+IW/CPE of 0.5, 0.7 and 0.9 during two consecutive *rabi* seasons of 2003-2004 and 2004-05 at research farm of CCS Haryana Agricultural University, Hisar. The experiment was laid out in split plot design with three replications. The upper soil layer of the experimental field was sandy loam, containing 63.6 % sand, 17.2 % silt and 19.2 % clay, having basic infiltration rate of 4.2 mm/h, had 20.5% moisture at -0.03 MPa and 7.2% at -1.5 MPa. After the harvest of preceding *kharif* crops of mungbean and sorghum, Wheat *cv*. WH 711 was sown on 2nd Dec. 2003 and 9th Dec. 2004 in conventional and on 1st Dec., 2003 and 4th Dec., 2004 in zero tillage (zero-tillage seed-cum fertilizer drill) practices, with a pre-sown irrigation. Glyphosate @2.5 l/ha (product) was applied after the harvest of mungbean and sorghum to control weeds in zero-till plots. Wheat was harvested in the 3rd week of April in both the seasons. The rainfall received during wheat crop season in 2003-04 was 25.5 mm and 137.9 mm in 2004-05 and the cumulative pan evaporation (CPE) for the two crop seasons was 409 and 361 mm, respectively. At sowing of wheat, the water table was 158 and 142 cm deep; fluctuated around 155 and 140 cm during the active growth period of the crop and was 175 and 148 cm at harvest in 2003-04 and 2004-05, respectively. A common irrigation was applied at CRI stage and thereafter, irrigations were applied in individual plot by flooding as per treatments based on IW/CPE ratios and the depth was measured with the help of current meter.

Moisture status of soil in the active root zone *i.e*., 0-90 cm was monitored with the help of soil moisture meter (Diviner) during the entire crop season. The moisture in entire root zone (90 cm) was computed by changes in the soil moisture content in the root zone during the crop period. Ground water contribution was calculated by estimating the flux density of the soil water from ground water table to root zone using Darcy's law for steady state conditions as proposed by Giesel *et al*. (1972), assuming that the flux entering the lower layer of the root zone is the potential contribution.

RESULTS AND DISCUSSION

Periodic Soil Moisture Depletion

In general, during 2003-04 crop season, relatively the moisture depletion from soil (0-90 cm) by wheat crop succeeding sorghum was higher during all the crop growth periods in comparison to mungbean, but the differences up to milk stage were not significant (Table 1). Difference between the two preceding crops for the soil moisture depletion during milk to maturity stage and for the entire crop season was however, significant. In the crop season 2004-05, the reverse trend was observed. Depletion of soil moisture by wheat after mungbean was more than that after sorghum. This was because of more extensive root system (density and depth) in wheat succeeding mungbean, and higher profile moisture storage by mungbean, being a legume crop resulting into higher depletion of moisture (Kumar, 2008). Planting of wheat under conventional tillage resulted in higher soil moisture depletion during both the crop seasons, but the differences between two tillage practices were significant for sowing to spike initiation stage and the entire crop period. The difference was also marked for milk to maturity stage in 2003-04. In zero-till wheat, the soil moisture depletion was lower than conventional tillage during both the crop seasons (Table 1). It may be primarily due to higher soil moisture conservation under zero tillage practice as observed by Mahey *et al*. (2002).

During 2003-04 crop season, the soil moisture depletion was significantly higher with irrigation moisture regimes of CRI + IW/CPE=0.5 at all the stages as well as for entire crop period, except during the initial stage of sowing to spike initiation as compared to the higher moisture regimes of irrigation at CRI + IW/CPE=0.9 and 0.7. The difference between irrigation at CRI + IW/CPE=0.9 and 0.7 was marked for anthesis to milk stage and for the entire crop period. In 2004-05, irrigation at CRI + IW/CPE=0.9 and 0.7 resulted in substantially higher soil moisture depletion during milk to maturity stage and for the entire crop period. Varying moisture regimes did not influence the soil moisture depletion during the early and development stages markedly. Maximum profile water depletion and actual evapo-transpiration of wheat occurred in the wetter moisture regime of IW:CPE of 1.2 than the lower ones in sandy loam soil and shallow water table (Bandyopadhyay and Mallick, 2003).

Table 1. Effect of preceding crops, tillage practices and moisture regimes on soil moisture depletion (mm) during various crop growth

Treatments	Crop periods (stages)				
	Sowing to spike initiation	Spike initiation to anthesis	Anthesis to milk	Milk to physiological maturity	Total
		2003-04			
Preceding crops					
Moong	23.9	20.6	18.8	28.8	92.0
Sorghum	24.9	21.5	19.3	30.3	96.0
SEm ±	0.4	0.7	0.4	0.4	1.1
LSD (P=0.05)	NS	NS	NS	1.4	3.8
Tillage practices					
Conventional	25.2	21.7	19.7	30.5	97.0
Zero tillage	23.7	20.3	18.4	28.6	91.0
LSD (P=0.05)	1.4	NS	NS	1.4	3.8
Moisture regimes : Irrigation at CRI + IW/CPE					
0.5	28.9	26.4	20.7	36.0	112.0
0.7	23.2	19.2	19.9	26.7	89.0
0.9	21.2	17.4	16.5	25.9	81.0
LSD (P=0.05)	NS	2.4	1.8	2.4	4.2
		2004-05			
Preceding crops					
Moong	19.3	14.9	15.6	26.8	76.5
Sorghum	18.7	14.0	14.7	25.1	72.5
LSD (P=0.05)	NS	NS	NS	1.6	2.4
Tillage practices					
Conventional	19.2	14.8	15.5	26.6	76.0
Zero tillage	18.8	14.1	14.8	25.3	73.0
LSD (P=0.05)	NS	NS	NS	NS	2.4
Moisture regimes : Irrigation at CRI + IW/CPE					
0.5	18.0	14.0	13.7	23.8	69.5
0.7	19.4	14.5	15.7	27.0	76.5
0.9	19.6	14.8	16.2	27.0	77.5
LSD (P=0.05)	NS	NS	NS	3.0	3.6

Periodic Ground Water Contribution

The water table of the field fluctuated around 150-160 cm in 2003-04 and 130-145 cm in 2004-05 during most of the crop period the flux from shallow ground water to meet the crop evapo-transpiration was estimated during different growth periods (Table 2). During 2003-04, the ground water flux succeeding moong was substantially higher (123 mm) than sorghum (111 mm) for the various crop stages, except the early growing period from sowing to spike initiation. In 2004-05, it was significantly higher during sowing to spike initiation and milk to maturity stages. It was also substantially more for the entire crop period. Higher ET requirement due to enhanced growth and hence yield (Musick *et al*., 1994) resulted in more uptake of water from soil and thus creating a gradient for upward movement of moisture from lower to upper soil layers.

Tillage practices in 2003-04 could not influence the ground water contribution up to milk stage. Zero tillage practice in wheat resulted in significantly higher ground water use than conventional tillage during milk to maturity stage as well as for the entire crop period. In 2004-05, ground water contribution towards crop ET followed almost the same trend as that of previous crop season. Increased hydraulic conductivity under zero than conventional tillage (Mc Garry *et al*., 2000) and non breakage of micro-pores resulted in increased upward flux from shallow ground water.

Higher moisture regimes of irrigation at CRI + IW/CPE=0.9 resulted in lower ground water use than CRI + IW/CPE=0.5 in 2003-04 during spike initiation to anthesis and milk to maturity stages. It was also substantially higher for the whole crop season. During 2004-05 crop season, the difference between above two moisture regimes was marked for milk to physiological stage and for the whole crop season. In both the crop seasons the difference between irrigation at CRI + IW/CPE=0.5 and 0.7 was not marked. The results are supported by the findings of Virdi (2003).

Table 2. Effect of preceding crops, tillage practices and moisture regimes on ground water use (mm) during various crop growth stages

Treatments	Crop periods (stages)				
	Sowing to spike initiation	Spike initiation to anthesis	Anthesis to milk	Milk to physiological maturity	Total
			2003-04		
Preceding crops					
Moong	14.9	27.0	21.8	59.4	123.0
Sorghum	15.0	25.0	18.6	52.5	111.0
LSD (P=0.05)	NS	1.4	2.1	4.8	7.9
Tillage practices					
Conventional	14.6	25.5	19.8	53.2	113.0
Zero tillage	15.3	26.5	20.5	58.7	121.0
LSD (P=0.05)	NS	NS	NS	4.8	7.9
Moisture regimes : Irrigation at CRI + IW/CPE					
0.5	14.9	28.5	20.0	59.6	123.0
0.7	14.9	25.3	21.3	54.5	116.0
0.9	15.0	24.1	19.2	53.7	112.0
LSD (P=0.05)	NS	1.5	NS	3.9	7.8
2004-05					
Preceding crops					
Moong	9.1	14.0	10.8	32.3	66.1
Sorghum	8.1	12.7	9.6	29.1	59.5
LSD (P=0.05)	0.7	NS	NS	3.1	6.2
Tillage practices					
Conventional	8.1	12.5	9.6	28.5	58.7
Zero tillage	9.1	14.3	10.7	32.8	67.0
LSD (P=0.05)	0.7	NS	NS	3.1	6.2
Moisture regimes : Irrigation at CRI + IW/CPE					
0.5	8.7	13.8	9.9	29.6	62.0
0.7	8.5	13.9	9.8	29.3	61.5
0.9	8.6	12.5	10.9	33.1	65.0
LSD (P=0.05)	NS	NS	NS	2.8	5.5

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Influence of bed planting method on soil physico-chemical properties under varying moisture regimes in clusterbean – wheat crop sequence

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ABSTRACT

A field experiment was conducted at Hisar to study the effect of two methods of planting *viz*. bed and conventional planting on physico-chemical properties of soil in clusterbean-wheat crop sequence at Soil Research Farm of Chaudhary Charan Singh Haryana Agricultural University, Hisar on sandy loam soil. The results indicated that planting of clusterbean on beds was found better as compared to conventional planting, while planting of wheat on bed was found to be statistically at par with conventional planting. The organic carbon (OC%) at 0-15 and 15-30 cm soil depths was higher in bed planting as compared to conventional flat sowing. However, the pH and EC were similar in both the planting methods. Bulk density in bed planting was lower than conventional flat sowing at 0-15 cm soil depth. Basic infiltration rate was almost similar in both the methods of planting.

Key words : Planting methods, organic matter, water use, crop yield

INTRODUCTION

The natural resources being affected by second generation problems include water, soils, fertilizers, other chemical inputs, air and people. Availability of land and water resources especially for agricultural purposes, is becoming scarcer in India. Surface irrigation is an ancient and widely used technique for irrigation in the Indo-Gangetic Plains of South Asia which accounts for low irrigation water use efficiency. Development of suitable crop-specific layouts can improve the application efficiency of available irrigation water resources. The bed and furrow irrigation method is one of the most efficient surface water application methods (Kahlown *et al.*, 1998). Wheat sown on beds resulted in lower runoff and soil erosion, lower rate of soil organic matter decrease and better soil structure in the 0-15 cm depth (Hulugalle *et al*., 2002). So, to achieve higher organic carbon content and other related benefits, one alternative is to plant crops on top of the raised beds and apply irrigation in furrows between the beds. Higher organic carbon content in bed planting is due to higher root biomass production and decrease in leaching losses due to limited contact with water. Therefore, the present study was undertaken to study the influence of bed planting method on soil physico-chemical properties under varying moisture regimes in clusterbean–wheat crop sequence.

MATERIALS AND METHODS

A field experiment was conducted to compare two methods of planting *viz*, bed and conventional planting in clusterbean-wheat crop-sequence during 2003-04 and 2004-05 at Research Farm of CCSHAU, Hisar on a sandy loam soil with 63.5% sand, 17.3% silt and 19.2% clay. The basic infiltration rate at the site was 5.3 mm/h and the gravimetric moisture content at -0.03 and -1.5 MPa soil water potential was 20.9 and 6.5% respectively. Soil was low in N, medium in P and high in K status. The soil contained 0.26% organic carbon content and pH was slightly alkaline (7.50). Bulk density of the soil was 1.58 g cm^{-3}. Clusterbean cv. HG-281 was planted in mid June at a row spacing of 45 cm under conventional planting and on beds using a bed planter. The width of the bed was 40 cm and two rows of clusterbean at 20 cm were planted on each side of the bed. The furrows were about 30 cm deep having a 'V' notch type shape. Thus, the effective distance between the two rows of the furrows was 70 cm. After the harvest of clusterbean, wheat *cv*. WH-711 was planted on 24^{th} November 2003 and 5^{th} November 2004 on same beds after reshaping with bed planter, following a pre-sown irrigation of 5.9 and 6.4 cm depth on 13^{th} November 2003 and 26^{th} October 2004 during the two *rabi* seasons. Wheat crop was harvested in the mid April during both the years. The physico-chemical properties were estimated in 0-15 cm and 15-30 cm depths after wheat harvest during the second year of experimentation in April 2005. Standard methods of the estimation, Core sampling (Piper, 1966) for bulk density, Ring infiltrometers for infiltration rate, Glass electrode pH meter (Jackson, 1973) for pH, Conductivity meter for EC and Walkely and Black rapid titration method (Piper, 1966) for Organic carbon were used.

RESULTS AND DISCUSSION

Average data of two years revealed that planting of clusterbean on beds produced 13.9 % higher grain yield than the flat sowing, while, statistically similar mean straw yield was produced under bed and conventional plantings (Fig. 1). Well developed root system in bed planting (Sewhag, 2005) might have resulted in better absorption of water and nutrients. The above findings can also be explained on the basis of the fact that clusterbean sown on beds resulted in good aeration and higher soil organic matter and better soil structure in the 0-15 cm depth. Similar were the findings of Raut *et al*. (2000). Bed planting showed pronounced effect on yield attributes and finally on the yield of clusterbean. Mean grain yield of wheat did not differ significantly due to planting methods. The Mean straw yield of wheat was significantly higher in conventional flat sowing as compared to bed planted wheat. These results are corroborated by Tripathi (1999) who reported lower value of yield attributes under permanent bed system than other planting systems of DT-flat and CT-beds.

The results on physico-chemical properties (pH, EC, OC%, BD and IR) showed that organic carbon (%) at both the soil depths was higher in bed planting compared to conventional flat sowing (Table 1). The increase in the organic carbon could be attributed to more retention of organic residues in bed planting treatment as compared to conventional tillage treatments. Corroborative findings have also been reported by Hulugalle *et al*. (2002). Higher organic carbon content in bed planting may also be due to higher root biomass production and decrease in leaching losses due to limited contact with water. Furthermore, there was lesser soil disturbance in bed planting than conventional planting.

Table 1. Physico-chemical properties of soil under bed and conventional planting system (after two years of experimentation)

Soil properties	Bed planting		Conventional planting	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm
pH (1 : 2)	8.1	8.2	8.1	8.3
EC (1 : 2)	0.69	0.53	0.62	0.51
OC (%)	0.48	0.23	0.37	0.19
BD (tm^{-3})	1.48	1.62	1.58	1.67
IR (mm/hr)	5.2	-	5.4	-

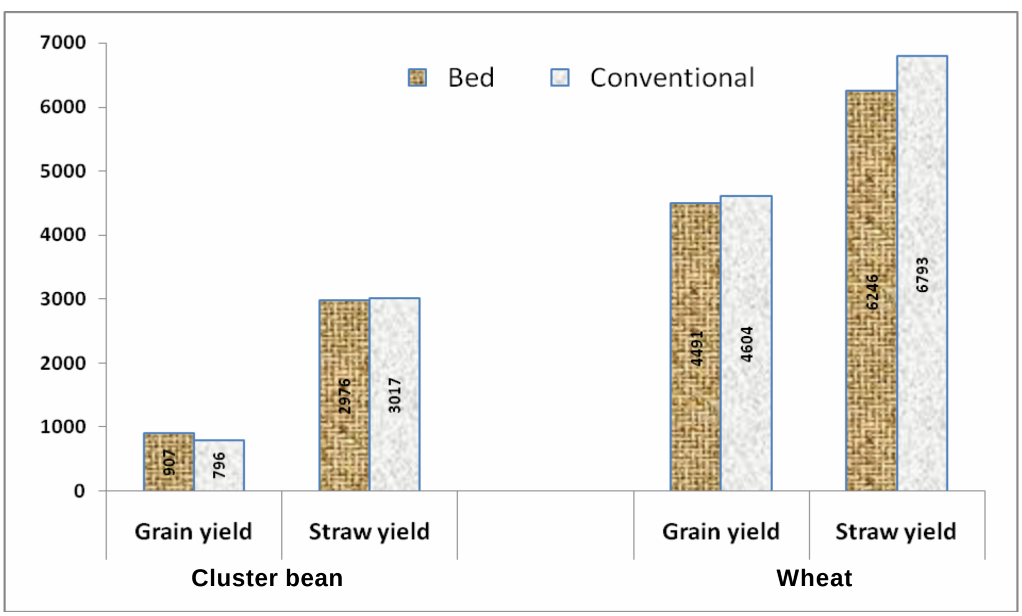

Fig. 1. Effect of planting methods grain and straw yield (kg/ha) of clusterbean and wheat (mean of two years)

Since beds were of permanent nature adding to cabon squestration. The surface layers usually had more water, cooler, less oxidative and more acidic (Doran, 1980). These conditions tend to cause the organic matter to increase or decrease at a slower rate compared to conventional planting. The pH and EC were similar in both the methods of planting. Bulk density of soil was influenced by soil texture, structure, organic matter content and land management practices. Bulk density in bed planting was lower than conventional flat sowing at 0-15 cm soil depth which might be due to increase in organic matter content. Soil porosity with bed planting was larger than for flat planting, resulting in lower bulk density. Basic infiltration rate was almost similar in both the methods of planting.

It may be concluded that planting of clusterbean on beds was better as compared to conventional planting. The planting of wheat on bed was statistically at par with conventional planting. The organic carbon (OC %) at both the soil depth were higher in bed planting as compared to conventional flat sowing. However, the pH and EC were similar in both the methods of planting. Bulk density in bed planting was lower than conventional flat sowing at 0-15 cm soil depth. Basic infiltration rate was almost similar in both the method of planting.

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Effect of seed soaking in various chemical solutions on seed germination of bitter gourd (*Momordica charantia* L.) varieties

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ABSTRACT

Seed germination study of two bitter gourd varieties Pusa Do Mausmi and Pusa Vishesh using eight chemicals and three seed soaking durations was carried out in March and August, 2009 under laboratory and field conditions. The treatment differences for seed germination and field emergence of both the varieties for respective seed soaking durations were highly significant. The varieties differed for seed germination in respective seed soaking durations under laboratory and field conditions where some interactions were also found significant. The trend of seed germination in laboratory and field emergence of seedlings in both the experiments and for all the three seed soaking durations was similar, where the field emergence of seedlings was found lesser than laboratory seed germination in all the treatments investigated. In both experiment GA_3 50 ppm followed by KCl 1% and $ZnSO_4$ 1% gave significantly higher seed germination than the canal water (control) treatment in both the varieties. Pusa Vishesh had better seed germination than Pusa Do Mausmi, however, field emergence was at par in both the varieties. Field emergence was recorded maximum with GA_3 50 ppm/boron 25 ppm and or GA_3 50 ppm/KCl 1% and KNO_3 1% and $ZnSO_4$ 1%. It was lowest with canal water and IBA 75 ppm. Seed soaking duration of 12h was better than 24 and 36h. Seed germination and field emergence were reduced with increased soaking duration of the seeds. The patterns of field emergence, which showed none-to-multi peaks was not consistent for the chemical response, seed soaking duration and also for the crop season. GA_3 50 ppm, KCl 1% and KNO_3 1% with 12 h seed soaking appeared most promising for enhancing seed germination and field emergence of bitter gourd varieties.

Key words : *Momordica charantia* varieties, seed germination, field emergence

INTRODUCTION

Bitter gourd (*Momordica charantia* L.), commonly known as *Karela,* is a popular cucurbitaceous vegetable crop mainly grown in tropical and subtropical regions of the world. In India, it is grown in Maharashtra, Kerala, Karnataka, Tamil Nadu, Uttar Pradesh and Bihar states during spring-summer and rainy seasons. It is a good source of vitamin A and vitamin C, potassium and magnesium (Bose and Som, 1986). Its immature fruits are valued high and useful in human diabetes and blood pressure problems. The quality of seed used and other cultural practices adopted actually determine its production. However, the poor seed germination, primarily due to hard seed coat even under normal field conditions, is a matter of great concern in bitter gourd.

Very scanty information on seed germination of bitter gourd (Sharma and Govil, 1985; Samdyan, 1991, Devi and Selvaraj, 1994; Yeh *et al.*, 2005 and Shantappa *et al.*, 2006) is available in literature. Further, most of such reports are inconclusive in nature to become any perfect recommendation. Consequently, to improve crop stand and uniformity in the field, there is need to enhance the seed germination of bitter gourd crop. Hence, to bring out any justified practical recommendation, the present investigation was carried out during summer and rainy seasons of 2009.

MATERIALS AND METHODS

The field experiment was conducted at Vegetable Research Farm and the Laboratory experiment in Department of Seed Science and Technology, CCS HAU, Hisar during summer and rainy seasons. Treatment wise 100 seeds of uniform weight and size of varieties -Pusa Do Mausmi and Pusa Vishesh for field study and 50 seeds each for laboratory experiment were soaked for 12, 24 and 36 hours in the solutions of seven chemicals of respective concentrations prepared just prior to soaking of seeds. While, canal water was eighth solution used as such a control treatment for seed soaking for each of the three durations. Field used for seed germination study had uniform fertility level and sandy loam soil texture. A pre-sowing irrigation was given to ensure adequate soil moisture for germination. The well pulverized and leveled field was divided into three smaller equal sized blocks constituting each replication with net plot area of 5 x 2 m accommodating a total of 16 rows representing eight single row treatments of each of the two varieties being tested for three seed soaking periods within each replication block repeated thrice.

Treatment wise soaked seed samples were sown on each plot in rows spaced 10 cm apart at 5 cm spacing uniformly in five-meter long single rows and arranged in randomized block design. Field emergence of seedlings that begun on 7th day after sowing was recorded as the number of seedlings emerged daily until the seed germination completed on 16th day during both the seasons. Per cent field emergence was calculated as per Maquire (1962). On the other hand, similar experiment was also conducted in laboratory in both the seasons (March and August, 2009). Here, treatment-wise all the samples of soaked fifty seeds were sown between towel paper method arranged in a completely randomized design with three replications and incubated in seed germination chamber at 25^{0}C. The seed germination was recorded on 14th day after sowing during both the sowing seasons. Data on estimates of the seed vigour and field emergence indices were analyzed following designs of experiments as per Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

Standard seed germination (%)

Chemical treatments resulted significant differences in seed germination of variety Pusa Do Mausmi for 12h seed soaking period only in experiment set-I (Table 1). Varietal differences were significant in all the three seed soaking durations and that of over all averages of the individual variety. Seed germination was better in Pusa Vishesh as compared to variety Pusa Do Mausmi under all the three seed soaking durations. In general, seed germination in both the varieties was observed above 70% for all the treatments except Pusa Do Mausmi in 12h seed soaking duration with canal water. The variety x treatment interaction was noted significant only for 12h seed soaking duration, where seed germination ranged from 62.33% in Pusa Do Mausmi with seed soaking in canal water to the maximum germination in Pusa Vishesh (90.67%) both with IBA 75 ppm and canal water seed soaking treatments. Among the treatments under laboratory conditions, seed germination was recorded the highest in IBA 75 ppm followed by GA_3 50 ppm and KCl 1%, whereas the lowest germination of 76.5% was with canal water followed by Boron 25 ppm and KNO_3 1% seed soaking treatments.

In experiment set-II sown in August all the variances except varieties x treatments interactions for 12 and 36h seed soaking were observed significant (Table 2). Varietal differences were also significant in this set of experiment, where germination was recorded better in Pusa Vishesh than Pusa Do Mausmi. With 12h seed soaking the seed germination was highest with GA_3 50 ppm followed by IBA 75 ppm, K_3PO_4 1%, $ZnSO_4$ 1% and KCl 1%. In 24h seed soaking durations the highest seed germination was observed with GA_3 followed by KCl 1% whereas, with 36h seed soaking duration, the GA_3 50 ppm was followed by $ZnSO_4$ 1% recording the highest seed germination. The over all mean for the treatment effects showed that GA_3 50 ppm followed by $ZnSO_4$ 1% and KCl 1% had resulted the maximum seed germination.

In all the three seed soaking durations with canal water as control, the seed germination was lowest but above 70%. With 24h seed soaking the interaction effects revealed that seed germination was maximum (95%) with GA_3 50 ppm in variety Pusa Do Mausmi while, it was also the highest for variety Pusa Vishesh, and in both the varieties the seed germination was the lowest for seed soaking in canal water. KNO_3 and IBA 75 ppm resulted increased seed germination in variety Pusa Vishesh, whereas $ZnSO_4$ 1% recorded reduced seed germination in Pusa Do Mausmi. Thus, in the present study, the significant varietal variation in seed germination over the chemical and their treatments durations have been noted. Similar variation for seed germination in bitter gourd was also observed by earlier workers (Samdyan, 1991; Devi and Selvaraj, 1994; Shantappa *et al.*, 2007 and Marshal *et al.*, 2008).

In both the sets of experiments GA_3 50 ppm followed by KCl 1% and $ZnSO_4$ 1% gave significantly higher seed germination than the canal water control treatment in both the varieties. Similar results were also reported by Sharma and Govil (1985) and Samdyan (1991) in bitter gourd. The seed soaking prior to sowing significantly improved seed germination over control in both the varieties investigated. Devi and Selvaraj (1994)

Table 1. Effect of seed soaking chemical treatments and duration on seed germination (%) in bitter gourd varieties under laboratory conditions during summer season 2009

Seed soaking chemical treatments	Per cent seed germination of two bitter gourd varieties under three seed soaking duration											Grand mean
	12h seed soaking			24h seed soaking			36h seed soaking			Mean		
	PDM*	PV*	Mean	PDM	PV	Mean	PDM	PV	Mean	PDM	PV	
T_1 KCl 1%	86.67	89.33	88.00	82.67	92.00	87.33	82.67	89.33	86.00	84.00	90.22	87.11
T_2 KNO_3 1%	78.67	81.33	80.00	81.33	86.67	84.00	81.33	88.00	84.67	80.44	85.33	82.89
T_3 K_3PO_4 1%	80.00	96.00	88.00	78.67	90.67	84.67	78.67	81.33	80.00	79.11	89.33	84.22
T_4 $ZnSO_4$ 1%	82.67	89.33	86.00	88.00	93.33	90.67	82.67	92.00	87.33	84.45	91.55	88.00
T_5 Boron 25 ppm	73.33	85.33	79.33	73.33	89.33	81.33	80.00	90.67	85.33	75.55	88.44	82.00
T_6 GA_3 50 ppm	86.67	89.33	88.00	82.67	82.67	82.67	77.33	84.00	80.67	82.22	85.33	83.78
T_7 IBA 75 ppm	86.67	90.67	88.67	84.00	89.33	86.67	81.33	84.00	82.67	82.67	88.00	85.34
T_8 Canal water	72.33	90.67	81.50	78.67	85.33	82.00	78.67	86.67	82.67	76.56	87.56	82.06
Mean	80.05	89.00	84.31	81.17	88.67	84.92	80.33	87.00	83.67	80.63	88.22	84.43
LSD (P=0.05)	12h seed soaking			24h seed soaking			36h seed soaking					
Varieties		3.21			3.50			2.67				
Treatments		6.41			NS			NS				
Var. x treatments		9.07			NS			NS				

*PV=Pusa Vishesh, PDM=Pusa Do Mausmi, NS=Non significant.

Table 2. Effect of seed soaking chemical treatments and duration on seed germination (%) in bitter gourd varieties under laboratory conditions during rainy season 2009

Seed soaking chemical treatments	Per cent seed germination of two bitter gourd varieties under three seed soaking duration											Grand mean
	12h seed soaking			24h seed soaking			36h seed soaking			Mean		
	PDM*	PV*	Mean	PDM	PV	Mean	PDM	PV	Mean	PDM	PV	
T_1 KCl 1%	82.67	81.33	82.00	82.67	84.00	83.33	68.00	85.33	76.67	77.78	83.55	80.67
T_2 KNO_3 1%	77.33	78.67	78.00	80.00	74.67	77.33	76.00	78.67	77.33	77.78	77.33	77.56
T_3 K_3PO_4 1%	80.00	86.67	83.33	80.00	81.33	80.67	70.67	80.00	75.33	76.89	82.67	79.78
T_4 $ZnSO_4$ 1%	78.67	86.67	82.67	78.67	82.67	80.67	78.67	85.33	82.00	78.67	84.89	81.78
T_5 Boron 25 ppm	70.67	82.67	76.67	82.67	80.00	81.33	77.33	89.33	83.33	76.89	84.00	80.45
T_6 $GA_3$50 ppm	84.00	84.00	84.00	94.67	80.00	87.33	76.00	82.67	79.33	84.89	82.22	83.56
T_7 IBA75 ppm	84.00	82.67	83.33	82.67	77.33	80.00	78.67	81.33	80.00	81.78	80.44	81.11
T_8 Canal water	70.67	78.67	74.67	77.33	66.67	72.00	57.33	65.33	61.33	68.44	70.22	69.33
Mean	78.52	82.67	80.58	82.33	78.34	80.34	72.83	80.99	79.91	77.89	80.67	79.28
LSD (P=0.05)	12h seed soaking			24h seed soaking			36h seed soaking					
Varieties		2.36			2.17			3.86				
Treatments		5.26			4.35			7.71				
Var. x treatments		NS			6.15			NS				

*PV=Pusa Vishesh, PDM=Pusa Do Mausmi, NS=Non significant.

followed the seed soaking for 12h where, most of the solutions increased seed germination with KNO_3 1% recording the highest. However, the present investigation showed improved seed germination in KNO_3 1% in 1st set of experiment and slightly above the control in the 2nd set of experiment.

Field emergence of seedlings (%)

The higher values of field emergence of seedlings, the interplay of seed germination process with the physical properties of soil and the environment, suggested early germination on account of specific treatment, while the lower values showed delayed and lesser emergence. The data on seed germination or field emergence of seedlings under field conditions, presented in Table 3 showed that all the variances except for varietal differences with 12h seed soaking in experiment set-I were significant. Here, with 12h seed soaking treatment both the varieties exhibited field emergence ar par. However, Pusa Do Mausmi had better field emergence than Pusa Vishesh with 24h seed soaking and this trend reversed with 36h seed soaking duration (Table 3).

GA_3 50 ppm followed by boron 25 ppm with 12h seed soaking treatment and GA_3 50 ppm followed by KCl 1% and KNO_3 1% with 24 and 36h seed soaking durations registered the maximum field emergence of seedlings while, it was recorded the lowest with canal water and IBA 75 ppm. The variety x treatment interaction revealed that seed soaking with GA_3 50 ppm and canal water in both the varieties for 12h recorded the maximum and the minimum field emergence, respectively while, KCl 1%, $ZnSO_4$ 1% and boron 25 ppm in Pusa Vishesh, and KNO_3 1% and IBA 75 ppm in Pusa Do Mausmi recorded higher field emergence than Pusa Vishesh.

In experiment set-II all the variances except varietal differences with all the three seed soaking durations and the interactions of varieties x treatments for 12h seed soaking duration were significant (Table 4). GA_3 50 ppm in all the three seed soaking durations recorded the highest field emergence in both the varieties. The 12 and 24h seed soaking with canal water and that of IBA 75 ppm with 36h seed soaking gave minimum field emergence. Almost all the treatment effects were significantly different from each other in all the three seed soaking durations. On mean basis, the treatments GA_3 50 ppm followed by $ZnSO_4$ 1% and Boron 25 ppm were the most effective for higher field emergence.

The interaction effects observed significant for treatments and varieties for 24 and 36h seed soaking durations suggested that the treatments of KCl 1%, KNO_3 1%, K_3PO_4 1%, Boron 25 ppm reduced or increased field emergence in either of the varieties. In case of seed soaking for 36h the field emergence was minimum with K_3PO_4 1% and IBA 75 ppm instead of the control canal water treatment. In general, field emergence depicted a decreasing trend from 12h seed soaking to 36h seed soaking durations. It appeared in contrast to the seed germination results in laboratory where similar effect was not visible. Moreover, the results of $ZnSO_4$ 1% and KCl 1% were not consistent during both the experiments. Such a response might be due to the ageing effect of the seeds. Devi and Selvaraj (1994) also reported difference in seed germination with soaking in different solutions as compared to untreated dry seeds. Likewise, Thirusenduraselvi and Jerlin (2009) also indicated that wet seeds excelled in all quality parameters in comparison to sowing of the dry seeds.

In the present study, the results of seed germination also corresponded with the results observed for field emergence. In general, the field emergence in both the varieties was lesser than the seed germination observed in the laboratory. However, some deviations in the results of seed germination and that of the field emergence with respect to varieties and the effects of different treatments have been noticed. These results suggested the notable change in the response status of both the varieties.

Apart from the seed germination assessment under laboratory conditions, the study of vigour parameters through this measure is a better option to authenticate the laboratory results. Accordingly to Matthews (1981) germination test results, that established the maximum plant producing potential of seed lots, were found correlated with field emergence. The germination test results were also found correlated with field emergence under favorable conditions (ISTA 1985). Similarly, Yadav and Dhankhar (2001) reported the association between field emergence and seed germination percentage.

Also, the pattern of daily seedling emergence up to the last counting day of seedlings in both the varieties with respect to the effect of respective treatments has been depicted in Figures 1 to 6 and 7 to 12. The graphical depiction of such pattern of the field emergence counts was in supplement to the percentage data shown in Tables 3 and 4 whereby the response behaviour of the varieties and the results of effect of the different chemical treatments shown through the peak period, duration, early or delayed emergence become visible and ultimately the effectiveness of the individual treatments could be judged precisely. The pattern exhibited peak field emergence from 8^{th} to 12^{th} day after sowing in both the bitter gourd varieties with 12 and

Table 3. Effect of seed soaking chemical treatments and seed soaking duration on field emergence of seedlings (%) in bitter gourd varieties under field conditions during summer season 2009

Seed soaking chemical treatments	Per cent seed germination of two bitter gourd varieties under three seed soaking duration											Grand mean
	12h seed soaking			24h seed soaking			36h seed soaking			Mean		
	PDM*	PV*	Mean	PDM	PV	Mean	PDM	PV	Mean	PDM	PV	
T_1 KCl 1%	72.00	87.00	79.50	74.00	72.00	73.00	62.00	74.00	68.00	69.33	77.67	73.50
T_2 KNO_3 1%	76.00	70.00	73.00	78.00	74.00	76.00	58.00	80.00	69.00	70.67	74.67	72.67
T_3 K_3PO_4 1%	70.00	71.00	70.50	70.33	55.00	62.67	64.00	63.00	63.50	68.11	63.00	65.56
T_4 $ZnSO_4$ 1%	68.00	78.00	73.00	71.00	55.00	63.00	68.00	58.00	63.00	69.00	63.67	66.34
T_5 Boron 25 ppm	82.00	86.00	84.00	78.00	51.00	64.50	64.00	54.00	59.00	74.67	63.67	69.17
T_6 $GA_3$50 ppm	86.00	80.00	83.00	81.67	85.00	83.34	70.00	78.00	74.00	79.22	81.00	80.11
T_7 IBA75 ppm	66.00	63.00	64.50	72.00	69.00	70.50	54.00	70.00	62.00	64.00	67.33	65.67
T_8 Canal water	64.00	58.00	61.00	68.00	70.00	69.00	69.00	66.00	67.50	67.00	64.67	65.84
Mean	73.00	74.12	73.56	73.56	66.33	70.23	63.62	67.87	65.75	70.25	69.46	69.86
LSD (P=0.05)	12h seed soaking			24h seed soaking			36h seed soaking					
Varieties		NS			2.38			2.70				
Treatments		5.75			4.77			5.40				
Var. x treatments		8.13			6.74			7.63				

*PV=Pusa Vishesh, PDM=Pusa Do Mausmi, NS=Non significant.

Table 4. Effect of seed soaking chemical treatments and seed soaking duration on field emergence of seedlings (%) in bitter gourd varieties under field conditions during rainy season 2009

Seed soaking chemical treatments	Per cent seed germination of two bitter gourd varieties under three seed soaking duration											Grand mean
	12h seed soaking			24h seed soaking			36h seed soaking			Mean		
	PDM*	PV*	Mean	PDM	PV	Mean	PDM	PV	Mean	PDM	PV	
T_1 KCl 1%	66.00	62.00	64.00	64.00	64.00	64.00	62.00	48.00	55.00	64.00	58.00	61.00
T_2 KNO_3 1%	52.00	58.00	55.00	64.00	66.00	65.00	57.30	60.00	58.65	57.77	61.33	59.55
T_3 K_3PO_4 1%	58.00	62.00	60.00	70.00	60.00	65.00	44.00	58.00	51.00	57.33	60.00	58.67
T_4 $ZnSO_4$ 1%	70.00	64.00	67.00	68.00	76.00	72.00	56.00	60.00	58.00	64.67	66.67	65.67
T_5 Boron 25 ppm	64.00	68.00	66.00	68.00	70.00	69.00	64.00	58.00	61.00	65.33	65.33	65.33
T_6 $GA_3$50 ppm	78.00	76.00	77.00	80.00	80.00	80.00	70.00	68.00	69.00	76.00	74.67	75.33
T_7 IBA75 ppm	62.00	62.00	62.00	60.00	68.00	64.00	52.00	52.00	52.00	58.00	60.67	59.33
T_8 Canal water	50.00	56.00	53.00	54.00	52.00	53.00	60.00	58.00	59.00	54.67	55.33	55.00
Mean	62.50	63.50	63.00	66.00	67.00	66.50	58.16	57.75	57.90	62.22	62.75	62.49
LSD (P=0.05)	12h seed soaking			24h seed soaking			36h seed soaking					
Varieties		NS			NS			NS				
Treatments		5.06			4.65			4.55				
Var. x treatments		NS			6.58			6.44				

*PV=Pusa Vishesh, PDM=Pusa Do Mausmi, NS=Non significant.

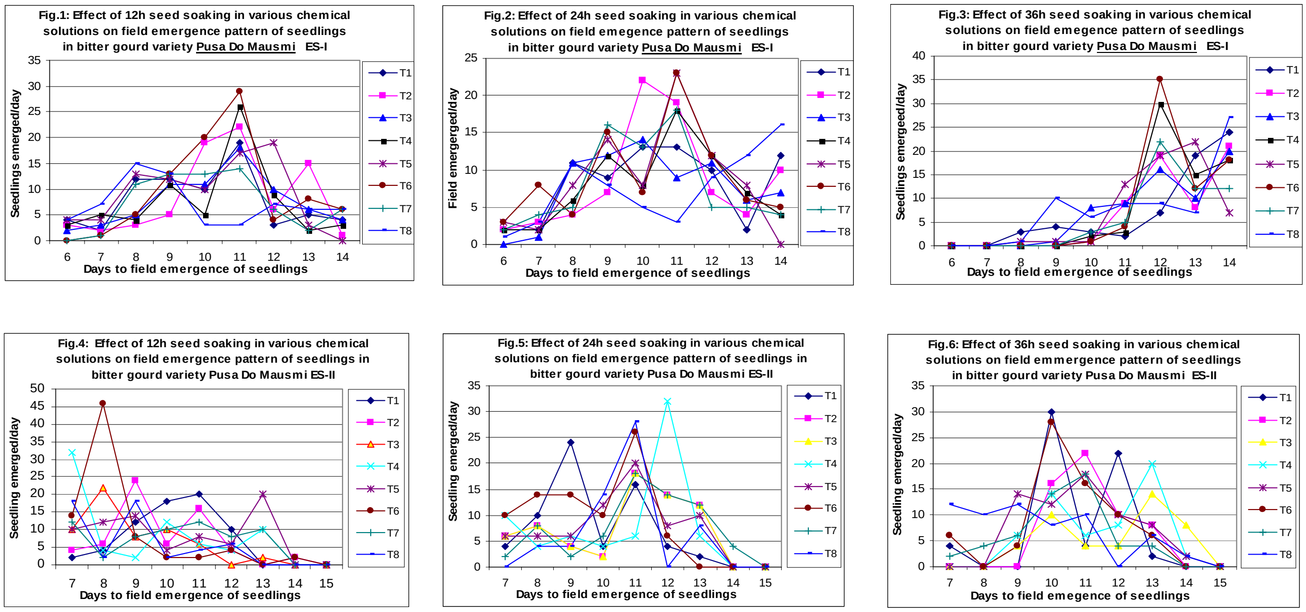

Fig. 1-6. Field emergence pattern of bitter gourd variety Pusa Do Mausmi observed in the field during summer and rainy seasons 2009 (Treatments T1 to T8 as per Tables 1-4)

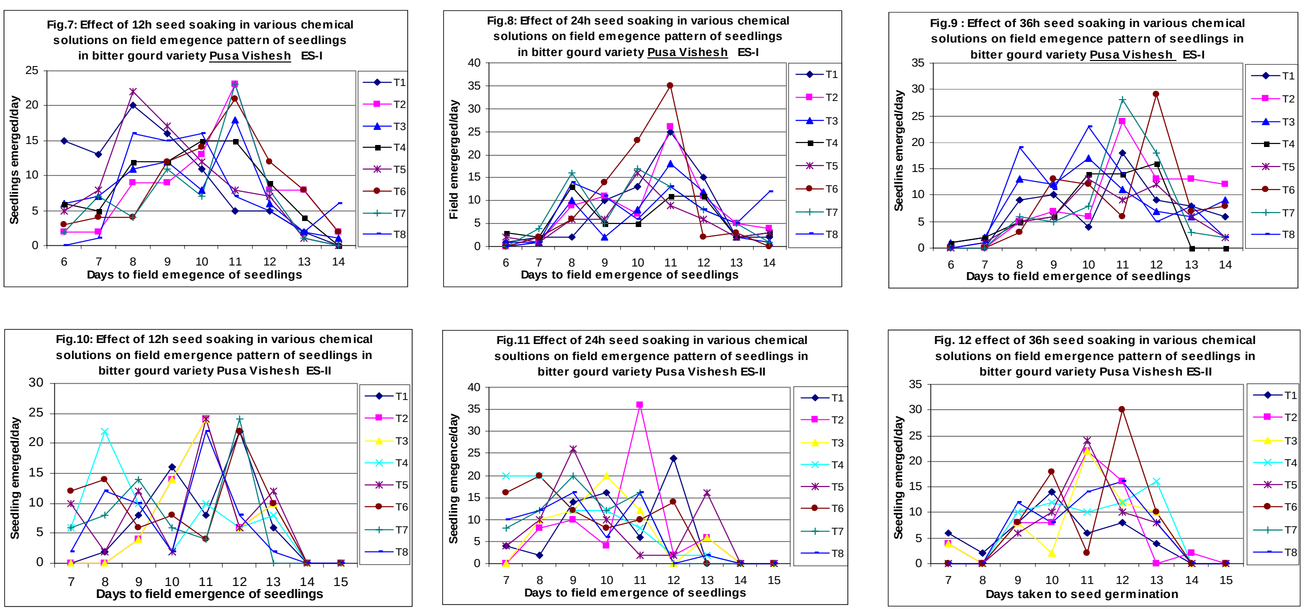

Fig. 7-12. Field emergence pattern of bitter gourd variety Pusa Vishesh observed in the field during summer and rainy seasons 2009 (Treatments T1 to T8 as per Tables 1-4)

24h seed soaking durations while, in Pusa Do Mausmi it was from 11-13[th] day in 1[st] set of experiment. The similar pattern was observed in 2[nd] set of experiment. Here, in both the seasons at least 2-3 peaks were noted for seed germination.

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Effect of crop geometry, nitrogen levels and intercropping on production of cauliflower (*Brassica oleracea* var. botrytis L.)

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ABSTRACT

A field experiment was conducted at Vegetable Research Farm of CCS Haryana Agricultural University, Hisar, India during *rabi* season of 2006 and 2007. In a split plot design, experimental treatments comprised two crop geometries i.e. 45 x 45 cm (normal spacing), 30/60 x 45 cm (paired rows) and three levels of nitrogen (125, 150 and 175 kg/ha) as main plot and five intercrops (beet leaf, fenugreek, garden beet, knol-khol and turnip) along with cauliflower as a monoculture control as sub plots. Crop geometry, nitrogen levels and intercrops significantly affected cauliflower yield . It was observed that crop geometry had significant effect on cauliflower yield parameters *viz*., plant weight, curd weight, biological and economical yield and the harvest index irrespective of N levels and intercrops planted. There was reduction in yield under paired row planting as compared to planting under normal spacing of 45 x 45 cm. Increasing levels of nitrogen increased the yield of cauliflower under different crop geometries and intercrops. All the intercrops grown in cauliflower significantly reduced yield parameters under all crop geometries and levels of nitrogen. The yields of all the intercrops in cauliflower was significantly reduced in normal spacing as compared to the paired row planting under all levels of nitrogen. Results of the study suggested for potential scope of intercropping in cauliflower, which could be well exploited using multi-cut leafy vegetables and other short duration turnip and garden beet varieties of root crops.

Key words : Beet leaf, cauliflower, fenugreek, garden beet, intercropping, knol-khol, turnip

INTRODUCTION

Intercropping of vegetables is attaining importance in India mainly due to increased cost of cultivation, dwindling economy of farmers, successive fragmentation of land holdings and rising demand of vegetables for massive population of our country. Vegetables are taken usually on high premium land in close proximity of the towns and cities, where the intercropping can prove useful not only for increasing total vegetable production but also getting substantial additional income from same piece of land during the same growing season and to make best use of the production resources.

Furthermore, the evolution of high yielding short duration varieties of vegetables has aroused the interest of cultivators for growing more crops than sole one during the whole year. Since, cauliflower crop is grown through seedlings transplanted at wider spacing, there remains sufficient space in between the rows particularly during its initial stages of growth, which provides good opportunity to utilize those inter row spaces for growing of some short duration vegetables as intercrops.

With these points in view, the scientific interest in intercropping developed over the past few decades to fully utilize the entire growing season and resources has greater relevance in the present context of escalating demand of vegetables for the mammoth population. Hence, a study was undertaken to explore the possibilities of intercropping various vegetables with cauliflower crop under Haryana conditions.

MATERIALS AND METHODS

The present investigation was carried out at Vegetable Research Farm of CCS Haryana Agricultural University, Hisar, India during *rabi* seasons of 2006 and 2007. The experiment was laid out in a split plot design with three replicates using a plot size of 3.15 x 3.6 m. The treatments comprised six combinations involving two crop geometries i. e. 45 x 45 cm (normal spacing) and 30/60 x 45 cm (paired rows); three levels of nitrogen (125, 150 and 175 kg/ha) along with recommended doses of P_2O_5 and K_2O (50 kg/ha) as main plots. The five different vegetables *viz.*, beet leaf, fenugreek, garden beet, knol-khol and turnip as intercrops were taken in sub-plots and within set the sole cauliflower crop was a check plot treatment.

The pre-raised, five week old healthy seedlings of cauliflower cv. Snow Ball-16 were transplanted in the field as per experimental plan accommodating 56 plants per plot of sole crop. As intercrops, the seeds of beet leaf (HS-23), fenugreek (Pusa Early Bunching), garden beet (Deteront Dark Red), and turnip (Purple Top White Globe) were sown and seedlings of knol-khol var. White Vienna were transplanted at a spacing of 20x5 cm, 20x5 cm; 20x10 cm, 20x10 cm and 20x5 cm, respectively. The full dose of phosphorus in the form of single super phosphate, potash in the form of muriate of potash and one-third dose of nitrogen in the form of calcium ammonium nitrate were applied as basal dose. Remaining two-third dose of nitrogen was top dressed in two equal splits at 30 and 45 days after transplanting. Uniform intercultural operations and plant protection measures were followed as and when required during the crop season. Harvesting of main crop was started in the second week of March during both the years.

RESULTS AND DISCUSSION

The data recorded on yield characters of cauliflower *viz.*, plant weight, curd weight, biological yield, economical yield and harvest index during both the years are presented in Table 1. It was observed that plants spaced at 45 x 45 cm produced significantly higher plant weight, curd weight biological yield and the economical yield as compared to those planted in paired rows (30/60 x 45 cm) during both the years. The crop geometry did not affect the harvest index significantly, however, a marginal increase in harvest index under 45 x 45 cm spacing was observed. Apparently, the altered crop geometry than the normal one had adverse effect on all these yield characteristics.

The effect of crop geometry was identical for growth characters, hence, due to lack of growth of plants, the yield reduced significantly. Owing to the planting of other intercrops, the increased competition for space and other growth resources also compounded the yield reduction effect. This reduction effect was more pronounced under paired row planting. These results are in close conformity with the findings of earlier workers (Csizinszky, 1995 and 1996; Das *et al*., 2000; Singh *et al.*, 2004) who also observed reduction in yield of cauliflower under reduced/narrow plant spacing. However, workers like Patil *et al.* (1995), Sharma and Chandra (2002), Singh (2005) and Amoli *et al*. (2007) reported higher curd yield of cauliflower at closer spacing than at wider spacing, which was probably due to the absence of intercrops.

The increasing dose of nitrogen from 125 to 175 kg/ha significantly increased all the yield parameters investigated *viz*., plant weight, curd weight, biological and economical yields (Table 1). Whereas, the increasing doses of nitrogen did not have significant effect on harvest index during both the years. However, it improved only slightly with increased nitrogen levels. The harvest index is a relative estimate of plant growth (biomass) and the marketable curd (economical component) both being equally affected under varying nitrogen levels, hence, the influence was least visible. The favourable effect of nitrogen was apparent because it is an important constituent of chlorophyll, nucleic acids and the proteins, which enhance the cell multiplication and elongation, and ultimately the elongation of the main growing shoots. In addition, nitrogen being an important essential and major plant nutrient, it is required in larger amount by the cauliflower plants (Borme *et al.*, 1987). Moreover, cauliflower is a heavy feeder of plant nutrients and under intercropping system, Csizinszky (1995 and 1996), Das *et al.* (2000), Sharma and Chandra (2002) and Singh *et al.* (2004) and Singh (2005) observed significant linear improvement in yield of main cauliflower crop as well as the inter crops with increased fertilizer doses. The results of the present study also corroborate the findings of these earlier workers.

The intercrops like garden beet and turnip interfered and reduced the cauliflower yield/ha to the maximum extent significantly, while beet leaf, fenugreek and knol-khol as intercrops least affected the plant weight, curd weight, biological yield and economical yield (Table 1). The effect of intercrops *viz.*, beet leaf, fenugreek and knol-khol on harvest index was found non-significant as compared to all other intercrops. The intercrops resulted in reduced harvest index during both the years where the decrease was significant over sole cauliflower crop (control) only. Thus, garden beet and turnip, which affected the yield characteristics of cauliflower, were not much suitable while, the other three intercrops where their greens were harvested as leafy or immature knobs produce appeared much profitable as intercrops in cauliflower irrespective of the crop geometry and nitrogen fertilizer levels applied.

Gawade *et al.* (2003), Yildirim and Guvenc (2005) and Hussain *et al.* (2005) studied intercropping

Table 1. Effect of crop geometry, nitrogen levels and intercrops on various yield parameters in cauliflower during the two years

Treatments	Plant weight (kg)			Curd weight (kg)			Biological yield (t/ha)			Economical yield (t/ha)			Harvest index (%)		
	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean
Crop geometry															
45 x 45 (cm)	1.036	1.055	1.045	0.555	0.575	0.565	24.3	25.6	25.0	13.4	14.1	13.8	55.2	55.0	55.1
30/60 x 45 (cm)*	0.947	0.975	0.961	0.520	0.544	0.532	23.5	24.6	24.1	13.0	13.5	13.2	55.2	54.9	55.1
LSD (P=0.05)	0.027	0.015	-	0.019	0.027	-	0.35	0.54	-	0.44	0.56	-	NS	NS	-
Nitrogen levels															
125 (kg/ha)	0.878	0.901	0.890	0.487	0.510	0.499	22.2	23.3	22.7	12.1	12.9	12.5	54.7	55.4	55.1
150 (kg/ha)	0.982	1.011	0.997	0.520	0.552	0.536	23.2	24.4	23.8	12.8	13.6	13.2	55.1	55.9	55.5
175 (kg/ha)	1.115	1.132	1.123	0.588	0.615	0.602	25.8	26.1	26.0	14.5	14.9	14.7	56.1	56.8	56.5
LSD (P=0.05)	0.033	0.019	-	0.023	0.033	-	0.43	0.66	-	0.54	0.68	-	NS	NS	-
Intercrops**															
Beet leaf	1.117	1.117	1.117	0.608	0.635	0.622	25.6	26.5	26.1	14.4	15.1	14.8	56.1	57.1	56.6
Fenugreek	1.122	1.142	1.132	0.614	0.637	0.626	25.8	26.8	26.3	14.6	15.3	14.9	56.4	57.2	56.8
Garden beet	0.972	0.994	0.983	0.570	0.592	0.581	25.3	25.5	25.4	14.2	14.5	14.3	56.1	56.9	56.5
Knol-khol	0.678	0.714	0.696	0.330	0.358	0.344	17.4	17.7	17.6	9.2	9.4	20.3	52.7	53.1	52.9
Turnip	0.817	0.850	0.834	0.425	0.438	0.432	21.5	22.2	21.9	11.4	12.0	11.7	53.1	54.0	53.5
Sole Cauliflower	1.244	1.272	1.258	0.675	0.697	0.686	27.3	28.5	27.9	15.5	16.4	16.0	54.5	55.2	54.9
LSD (P=0.05)	0.040	0.042	-	0.049	0.052	-	0.66	0.84	-	0.67	0.85	-	2.1	2. 0	-

*Paired row planting of cauliflower seedlings

**HS-23, Pusa Early Bunching, Deterant Dark Red, White Vienna & Purple Top White Globe varieties of respective intercrops were tested in cauliflower with crops like palak (*Beta vulgaris* var. bengalensis) radish, fenugreek (*Trigonella foenum-graecum*), coriander, dil (*Anethum graveolens*), onion, lettuce and snap bean. Radish, being fast growing and becoming ready for harvest in a short span of one month, did not interfere much with cauliflower at its initial stage of growth. Likewise among these palak (beet leaf), fenugreek and onion were found suitable intercrops.

Kaur and Khurana (2008) reported that intercrop combination of cauliflower+tomato followed by cauliflower + capsicum was the most potential in terms of production and monetary returns than their sole crops. Agarwal *et al.* (2010), Unlu *et al.* (2010) also suggested that intercropping of fenugreek, lettuce, pea, leek, onion and garlic had no negative effect on the yield and size of curds of cauliflower and broccoli. Fenugreek, leek, onion and garlic performed as best intercrops mainly due to their upright growth habit. Thus, results of the present study suggested for potential scope of such intercrops in cauliflower, which could be exploited further with the alteration or supplements of other multi-cut leafy vegetables and short duration varieties of root crops like turnip, radish and garden beet etc.

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Effect of intercropping on various growth characteristics of cauliflower

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ABSTRACT

A field experiment to study the effect of intercropping on growth characteristics of cauliflower cv. Snowball-16 was conducted at Vegetable Research Farm of CCS Haryana Agricultural University, Hisar, India during *rabi* seasons of 2006 and 2007. Two crop geometries i.e. 45 x 45 cm (normal spacing) and 30/60 x 45 cm (paired row planting) along with three levels of nitrogen (125, 150 and 175 kg/ha) comprised the main plots. Whereas, the five intercrops *viz.*, beet leaf, fenugreek, garden beet, knol-khol and turnip (including sole cauliflower crop as check) comprised the sub plots in split plot design. Crop geometry had significant effect on growth parameters of cauliflower *viz.*, plant height and number of leaves per plant at 30, 60 and 90 days after transplanting, days to 50% curd initiation and maturity irrespective of the nitrogen levels applied and intercrops planted. Compared to normal spacing of 45 x 45 cm, there was reduction in plant height and leaves per plant and delay in both curd initiation and maturity under paired row planting. The increasing level of nitrogen increased the curd yield, plant height and leaves per plant but delayed initiation as well as maturity of curds in cauliflower irrespective of crop geometries and intercrops. All the intercrops grown in cauliflower significantly reduced the plant height, leaves per plant and delayed both curd initiation and maturity in cauliflower under all crop geometries and levels of nitrogen. Delay was found more pronounced with turnip followed by garden beet and beet leaf as intercrops. The net returns were high with inter crops of beet leaf followed by fenugreek and garden beet. Study suggested the scope for multi-cutting leafy and short duration garden beet vegetables as potential intercrops in cauliflower. Turnip and knol-khol were at par with sole cauliflower crop.

Key words : Beet leaf, *Brassica oleracea* var. botrytis, cauliflower, fenugreek, garden beet, intercropping, knol-khol, turnip

INTRODUCTION

India requires abundance of food grains, fruits, vegetables and other food items to feed its alarmingly huge population. Among these food items, vegetables are usually raised on high valued peri-urban land. Furthermore, for economy in space utilization, savings on tillage costs, better utilization of surplus nutrients, solar energy and soil moisture reserves, increasing production and gross returns from per unit land area during the same growing season, the intercropping of vegetables is proving advantageous. Besides this, with the evolution of high yielding and short duration varieties of vegetables, now the cultivators are able to raise multiple, mixture and intercrops than growing the sole crop during the whole year.

The cauliflower is planted through seedlings in rows at wider spacing. In its initial stages, the growth of seedlings is quite slow and crop reaches marketable maturity in about 110-130 days. Therefore, sufficient space remaining unutilized and available in between the rows offer good opportunity for growers to raise short duration and high yielding varieties of various vegetables like beet leaf, fenugreek, garden beet, knol-khol, and turnip etc. as intercrops for both additional production and remuneration. With these facts in view, the scientific knowledge generated to utilize efficiently the entire space, growing season and available resources has greater relevance in the present context of feeding the ever rising population of the country. Hence, an investigation was undertaken to explore possibilities and suitability of intercropping various vegetables in cauliflower and to see their effects on its growth.

MATERIALS AND METHODS

The present study was undertaken at Vegetable Research Farm of CCS Haryana Agricultural University, Hisar, India for two years during *rabi* seasons in 2006 and 2007. The treatments comprised the six combinations involving two crop geometry i.e. 45 x 45 cm (normal spacing) and 30/60 x 45 cm (paired rows); three levels of nitrogen (125, 150 and 175 kg/ha) plus recommended doses of P_2O_5 and K_2O (50 kg/ha) as main plots. The five different vegetable intercrops *viz.*, beet leaf, fenugreek, garden beet, knol-khol and turnip were taken as sub-plots including the sole cauliflower crop as check treatment. The experiment was laid out in a split plot design with three replicates using a plot size of 3.15 m x 3.6 m per treatment.

Five weeks old and healthy seedlings of cauliflower cv. Snowball-16 were transplanted in the field as per experimental plan with each plot accommodating 56 plants of sole crop. Seeds of beet leaf cv. HS-23, fenugreek cv. Pusa Early Bunching, garden beet cv. Deteront Dark Red and turnip cv. Purple Top White Globe were direct sown as intercrops and the five weeks old healthy seedlings of knol-khol cv. White Vienna as intercrop were transplanted at a spacing of 20 cm x 5 cm, 20 cm x 5 cm; 20 cm x 10 cm, 20 cm x 10 cm and 20 cm x 5 cm, respectively. The full dose of phosphorus, potash and one-third dose of nitrogen were given as basal dose. Remaining two third dose of nitrogen was top dressed in two equal splits at 30 and 45 days after transplanting of the cauliflower seedlings. Uniform intercultural operations and plant protection measures were adopted during the crop season. Harvesting of cauliflower was started at an ideal compact curd stage in second week of March during both the years.

RESULTS AND DISCUSSION

Observations recorded on growth characters of cauliflower *viz.*, plant height and number of leaves per plant at 30, 60 and 90 days after transplanting (DAT), and days taken to 50% curd initiation and maturity during both the years are presented in Tables 1 and 2. The treatment effects of main and sub plots independently differed significantly, however, their interaction effects expressed no such differences. Data revealed that plants spaced at 45x45 cm produced significantly taller plants bearing more number of leaves per plant at 30, 60 and 90 DAT (Table 1). This normal spacing also resulted in early 50% curd initiation, curd maturity as well increased curd yield as compared to those planted in paired rows (30/60 x 45cm) during both the years (Table 2). Thus, under later planting system, the altered crop geometry

Table 1 Effect of crop geometry, nitrogen levels and intercrops on various growth of cauliflower cv.Snowball-16

Treatments	Plant height (cm)						Number of leaves per plant					
	2006			2007			2006			2007		
	Days after transplanting											
	30	60	90	30	60	90	30	60	90	30	60	90
Crop geometry												
45 x 45 (cm)	14.5	21.8	29.8	14.4	21.7	29.8	11.2	15.5	19.1	10.1	13.9	19.9
30/60 x 45 (cm)*	13.2	20.3	28.2	13.2	20.5	28.6	9.9	14.4	17.9	9.3	12.8	18.7
LSD (P=0.05)	0.47	0.51	1.01	0.38	0.35	0.92	0.37	0.46	0.89	0.19	0.39	0.90
Nitrogen levels												
125 (kg/ha)	11.9	19.0	26.9	11.8	19.2	27.4	9.0	13.5	16.9	8.4	11.9	17.7
150 (kg/ha)	13.8	21.2	29.1	13.9	21.2	29.3	10.5	14.9	18.7	9.7	13.4	19.3
175 (kg/ha)	15.7	23.1	31.1	15.6	22.9	30.8	12.2	16.5	20.1	11.0	14.7	21.0
LSD (P=0.05)	0.57	0.62	1.24	0.46	0.43	1.13	0.45	0.56	1.09	0.23	0.48	1.11
Intercrops**												
Beet leaf	14.2	22.2	30.2	14.2	22.2	29.8	10.4	15.5	19.3	9.7	14.6	20.5
Fenugreek	14.3	22.5	30.3	14.3	22.3	30.3	11.2	16.0	20.3	9.8	14.7	21.3
Garden beet	13.7	20.7	28.8	14.0	21.2	29.2	9.7	13.8	18.1	9.0	11.5	18.8
Knol-khol	11.4	16.5	24.5	12.2	17.2	25.3	9.9	13.9	15.0	9.4	12.2	15.7
Turnip	11.5	17.7	27.1	11.8	17.8	27.3	10.3	13.7	17.2	8.8	10.5	17.5
Cauliflower (Sole)	17.8	26.8	33.3	16.2	26.2	33.2	12.1	17.1	21.4	11.5	16.5	22.0
LSD (P=0.05)	1.19	1.12	1.68	0.89	0.84	1.55	0.77	0.84	1.43	0.76	0.62	1.22

*Paired row planting of cauliflower seedlings

**Varieties HS-23, Pusa Early Bunching, Deteront Dark Red, White Vienna & Purple Top White Globe of intercrops tested

Table 2. Effect of crop geometry, nitrogen levels and intercrops on curd initiation, maturity, yield and net returns in califlower cv. Snowall-16

Treatment	Days to 50% curd initiation			Days to 50% curd maturity			Curd yield (t/ha)			Net returns (Rs./ha)		
	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean
Crop geometry												
45 cm x 45 cm	77.7	73.9	75.8	97.6	91.7	94.6	13.4	14.1	13.7	104707	112347	108527
30/60cm x 45cm*	79.6	75.2	77.4	98.9	93.7	96.3	13.0	13.5	13.2	98523	103760	101142
CD (P=0.05)	0.28	0.34	-	0.17	0.35	-	0.40	0.56	-	-	-	-
Nitrogen levels												
125 (kg/ha)	77.7	73.5	75.6	97.0	91.4	94.2	12.1	12.9	12.5	95655	102075	98865
150 (kg/ha)	78.6	74.4	76.5	98.2	92.8	95.5	12.8	13.6	13.2	98510	106505	102508
175 (kg/ha)	79.7	75.6	77.7	99.5	93.8	96.7	14.5	14.9	14.7	110680	115580	113130
CD (P=0.05)	0.34	0.42	-	0.20	0.45	-	0.54	0.68	-	-	-	-
Intercrops**												
Beet leaf	78.5	72.8	75.7	97.0	90.5	93.8	14.4	15.1	14.8	143905	149675	146790
Fenugreek	78.7	72.5	75.6	97.8	91.0	94.4	14.6	15.3	14.9	132917	141308	137113
Garden beet	78.7	73.5	76.1	98.7	91.8	95.3	14.2	14.5	14.3	127283	131897	129590
Knol-khol	82.4	80.5	81.5	102.8	99.0	100.9	9.2	9.4	9.3	118497	124438	121468
Turnip	81.5	77.8	79.7	79.7	101.5	96.0	11.4	12.0	11.7	114802	119763	117283
Cauliflower (sole)	72.2	70.0	71.1	91.5	87.7	89.6	15.5	16.4	16.0	118313	127215	122764
CD (P=0.05)	0.62	0.70	-	0.71	0.79	-	0.67	0.85	-	-	-	-

*Paired row planting of cauliflower seedlings, Values given in parenthesis (bold case) are the yield of respective intercrops
**Varieties HS-23, Pusa Early Bunching, Deteront Dark Red, White Vienna & Purple Top White Globe of intercrops tested

than the normal one, exhibited adverse effect on these growth characters. Growing of intercrops due to competition for production resources compounded this adverse effect on cauliflower main crop. These results agree with the findings of Khurana *et al.* (1987), who observed similar effect of closer planting in cauliflower. Csizinszky (1996) reported that yields were higher at 38 cm than at 31 cm spacing. Singh (2005) also observed significant improvement in number of leaves, curd weight and yield in cauliflower at wider spacing of 45 cm x 60 cm than closer spacing (45 cm x 30 cm and 45 cm x 45 cm). The increasing levels of nitrogen from 125 to 175 kg/ha significantly increased the curd yield, plant height and number of leaves per plant at 30, 60 and 90 DAP and delayed 50% curd initiation as well as maturity during both the years (Tables 1 and 2).

The trend observed in the effects of nitrogen was identical and independent of the crop geometry and intercrops since its interaction effects exhibited no significant differences. Nitrogen, which is an essential major plant nutrient, forms an important constituent of chlorophyll, nucleic acids and proteins, consequently favoured cell multi-plication and ultimately the elongation of growing shoots. Hence, with increasing levels of nitrogen, the increased plant height, and the number of leaves per plant at all the three stages of growth was recorded. Curd yield increased significantly with increased nitrogen level. Furthermore, being heavy feeder of plant nutrients especially the nitrogen, cauliflower requires greater quantity of it for growth and production (Borme *et al.*, 1987).

The net returns also recorded the same pattern of decreasing and increasing with closer spacing and increased nitrogen levels, respectively. The intercrops like knol-khol followed by turnip and garden beet interfered and significantly reduced the plant height and number of leaves per plant to the maximum extent, while beet leaf and fenugreek as intercrops least reduced these traits over sole cauliflower crop (Tables 1and 2). Regarding intercrops, the highest net return was recorded with beet leaf followed by fenugreek and garden beet. Turnip and knol-khol inter-cropping was at par with sole crop of cauliflower. Thus, garden beet, knol-khol and turnip were not much suitable intercrops while, two other crops, where their greens were harvested as leafy produce, appeared much profitable intercrops irrespective of crop geometry and nitrogen levels applied.

These results are in agreement with the findings of Yildirim and Guvenc (2005) who tried lettuce, radish, onion and snap bean as intercrops in cauliflower and found that except radish other intercrops did not affect the growth and yield of cauliflower. However, intercropping of lettuce and onion in cauliflower resulted higher yield and returns. Likewise, Agrawal *et al.* (2010) found intercropping of fenugreek in cauliflower as the most potential combination for yield and net returns. Similar to the results of present investigation (Table 1), the yield and curd size in cauliflower were affected negatively with radish, peas, green beans and lettuce hence, these proved as unsuccessful intercrops in cauliflower. However, leak, onion and garlic performed as best intercrops mainly due to their upright growth habit (Unlu *et al.* (2010). Present study exhibited potential of intercropping leafy and root vegetables in cauliflower.

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Demonstrating improved production technology of green gram at farmers' fields

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ABSTRACT

Front line demonstrations on green gram [*Vigna radiata* (L.) Wilczek] were conducted at the farmers' fields during *kharif* 2005 and 2006 in 14 villages of Hisar district situated in semiarid environment of Haryana state to compare the productivity and profitability under improved production technology (IPT) *vis-a-vis* farmers' practices (FP). The use of IPT in 20 demonstrations resulted in 26.7% higher grain yield of green gram over the FP. An extension gap of 175 kg/ha between demonstrations and FP was recorded due to adoption of IPT and non-monetary factors under demonstrations. On an average basis, technology gap (420 kg/ha) and technology index (32.7 %) reflected the inadequate IPT for harvesting its potential yield. The mere investment on critical inputs (Rs.657/ha) and adoption of IPT gave additional returns of Rs.4970/ha and effective gain of Rs.4313/ha. The incremental benefit-cost ratio (IBCR) ranged between 7.04 to 8.10 averaging 7.57 during the study period. Technological breakthroughs, efficient extension network, congenial weather conditions and stable market are considered essential for attaining the potential yield of green gram.

Key words : Demonstration, green gram, technology gap, technology index, stable market

INTRODUCTION

Productivity of green gram [*Vigna radiata* (L.) Wilczek] is low in Haryana owing to its cultivation on light textured, dunal sand, degraded, marginal and sub marginal soils under small land holdings with harsh climate in dryland areas. Its productivity is also low in Hisar district. Traditional farmers' practices (FP) often result in low yields. On account of great risk involved, resource poor farmers of rain-fed areas hesitate to use costly inputs. Adequate information on effect of IPT on grain yield of green gram under rain—fed conditions was meager. The investigation was, therefore, undertaken at farmers' fields to demonstrate the production potential of latest IPT *vis-à-vis* FP and also to evaluate existing technologies .

MATERIALS AND METHODS

Demonstrations at farmers' fields through Krishi Vigyan Kendra, Sadalpur of CCS HAU, Hisar were conducted on green gram [*Vigna radiata* (L) Wilczek] at 10 locations i.e. in Durjanpur, Gunjar, Dobhi, Malapur, Kanoh, Sadalpur, Ludas and Juglan villages during *kharif* 2005 season and at 10 locations in Gangwa, Chhoti Rawalwas, Mohabbat Pur, Arya Nagar, Bagla, Sadal Pur and Sadal Pur Dhani villages during *kharif* 2006 season to evaluate the production potential and profitability under IPT in comparison with FP under semi- arid environment of Hisar district (Haryana). The soils of demonstration sites were alluvial sandy loam to loamy sand (*Typic ustochrepts*) in texture, rated as poor in organic carbon, low in nitrogen, medium in phosphorus and medium to high in potash with slight alkaline pH ranging from 7.9 to 8.3. The plot size for each demonstration was kept as 0.4 ha . Before lay out of the demonstrations, all the selected farmers were imparted training. In demonstrations, the farmers were provided quality seeds of MH 96-1 (Muskan) in 2005 and MH 83-20 (Asha) in 2006 along with bio-fertilizers, fertilizers and need based pesticides. After the onset of south –west monsoon, sowing of green gram on well prepared and weed free fields was done at 45 x 15 cm spacing on 8-11 July, 2005 and 9-12 July, 2006 by pora method by using *Rhizobium* and PSB culture inoculated seeds @ 15 kg/ha. All the recommended agronomic practices were timely performed in demonstration plots. In comparison, each of the selected farmer raised green gram crop in 0.4 ha area by using his own practices. About 387 mm rainfall was received in the area in 14 days in the months of July (195.9 mm, 5 days), August (9.4 mm, 1 day) and September (181.3 mm, 8 days) during crop season of *kharif* 2005 and 169 mm rainfall in 12 days in the months of July (91.3 mm, 8 days), August (7.9 mm, 2 days) and September (69.8 mm, 2 days) during crop season of *kharif* 2006.

The crop experienced dry spells of about 4 weeks and 2 weeks durations during 2005 and 2006, respectively, hence, slight to mild moisture stress during after noon hours were observed during 2[nd] week of August to 1[st] week of September. At this stage, the farmers having canal water, applied a light protective irrigation to the crop. The harvesting of crop was timely started at maturity (74-76 DAS) during both the years. The yields were obtained and data on output and input/ha were collected both from frontline demonstration plots and the farmers following traditional practices. The yield gap, cost and returns were calculated using weighted means in such a way as suggested by Prasad *et al*. (1993). The following formulae were used to estimate the gaps and index:

a. Extension gap (kg/ha)=Demonstration yield (Di)-Farmers Practices yield(Fi)
b. Technology gap (kg/ha)=Potential yield (Pi)-Demonstration yield (Di)
c. Technology index (%)= $\frac{(Pi-Di)}{Pi} \times 100$
d. Additional returns (Rs/ha)=(Di -Fi) x Sale price
e. Effective gain (Rs/ha)=Additional returns-Additional cost
f. Incremental benefit cost ratio (IBCR) = $\frac{\text{Additional returns}}{\text{Additional cost of cash inputs}}$

RESULTS AND DISCUSSION

Grain Yield

The package of IPT enhanced the grain yield ranging from 20.0 to 33.4 % over the FP and on an average 26.7 % during both the years (Table 1). Enhanced grain yield might have been due to IPT in the form of recommended package of practices including quality seed, proper plant population, use of biofertilizers, fertilizers, moisture conservation, timely weed removal and insect-pest control measures. Enhanced grain yields have been reported by Ali (1994) and Oad and Burio (2005).

Extension Gap

Extension gap was calculated as yield differences between IPT and FP. It was more during 2005 as compared to 2006. On an average of 20 demonstrations, the extension gap was recorded as 175 kg/ha. This gap could be attributed to poor adoption of aforesaid practices under FP. Such gap revealed about the essence of IPT adopted in frontline demonstrations. The lower extension gap reflected good extension activities. The gap could have been lowered down further by strengthening extension activities.

Technology Gap and Index

The technology gap ranged from 300 to 540 kg/ha. There was inverse relation between technology gap and extension gap. The higher technology gap did not show the existence of IPT under real farming situation. Though the frontline demonstrations were conducted under the supervision of experts, yet there was still a wide gap of 420 kg/ha between crop's potential yield and front line demonstration yields. This was due to abiotic stresses, differential soil fertility status and location specific management problems. The technology index, a yard stick of adoption of IPT, was higher (40.4%) during 2005 and lower (25.0 %) during 2006 and average (32.7%) in accordance with the technology gap. Its lower value, as a function of technology gap, indicated the higher perfection of IPT.

Table 1. Mean grain yield and gap analysis of frontline demonstrations on green gram

Year	No. of demonst-ration	Variety	Grain yield (kg/ha)		Potential yield (kg/ha)	Increase in grain yield over FP (kg/ha)	Extension gap (kg/ha)	Technology gap (kg/ha)	Technology index (%)
			I PT	F P					
2005	10	MH 96-1 (Muskan)	800	600	1340	33.4	200	540	40.4
2006	10	MH 83-20 (Asha)	900	750	1200	20.0	150	300	25.0
Average	-		850	675	-	26.7	175	420	32.7

Economic Analysis

Both grain yield variations and deviations in the sale price of green gram in the months of September to November on yearly basis influenced the total monetary returns (Table 2). The higher grain yield coupled with higher sale price during 2006 resulted in higher total returns. Additional returns of Rs 5120/ha and effective gain of Rs 4490/ha were recorded higher during 2005 than their respective values of Rs 4820/ha and Rs 4136/ ha during 2006. On an average, incurring Rs.657/ha additionally under IPT resulted in Rs.4970/ha additional returns over the FP. This amount of Rs.657/ha is so less that even a small and marginal farmer can afford it easily. The higher effective gain of Rs. 4490/ha) was recorded during 2005 with an average of Rs. 4313/ha during both the years of study. The increment benefit cost ratio (IBCR) ranged from 7.04 to 8.10 during both the years averaging 7.57. It meant that by incurring one more rupee on IPT, the farmer received a benefit of Rs.7.57. The results of this study are in line with the findings of Sidhu *et al*. (2003).The rural social milieu, poor marketing and credit support along with inadequate storage facilities were also noticed and discussed with the farmers in creating obstacles in effective transfer of IPT.

Table 2.Economic evaluation of frontline demonstrations vis a vis farmers practices on green gram

Year	Cost of inputs (Rs./ha)		Stable sale price of grains of	Total returns (Rs./ha)		Additional cost in demonstration (Rs./ha)	Additional returns in demonstration (Rs./ha)	Effective gain (Rs./ha)	Incremental benefit cost rario (IBCR)
	IPT	FP		IPT	FP				
2005	4680	4050	2500	20900	15780	630	5120	4490	8.10
2006	4788	4104	3100	29070	24250	684	4820	4136	7.04
Average	4734	4077	-	24985	20015	657	4970	4313	7.57

Inclusive of returns from stover

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Response of fodder sorghum (*Sorghum bicolor L.)* to nitrogen and phosphorus nutrition–A review

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ABSTRACT

Sorghum is a nutrient exhaustive crop and its productivity is low because of insufficient supply or sub optimal use of nutrients in general and nitrogen and phosphorous in particular. The phosphorous application is important due to its key role in root development, regeneration, energy transformation and metabolic processes of plant. Therefore, the purpose of this review is to study the literature pertaining to response of fodder sorghum to nitrogen and phosphorus nutrition so that the production of sorghum may be increased per unit area per unit time with optimum dose of nitrogen and phosphorus. A dose of 80 kg N/ha and 40 kg P_2O_5/ha produces significantly higher green and dry fodder yield than lower levels of N & P_2O_5 fertilization. Split application of nitrogen produces higher yield in sandy loam soils.

Key words : Balanced feeding, livestock health, productivity, multicut sorghum, split, application

INTRODUCTION

In Indian agriculture, animal husbandry is closely linked with crop production programme as a complementary enterprise. On one hand, crops particularly forages are of prime importance for balanced feeding of animals and on the other hand, the livestock through supply of organic manures and draft power helps in optimum growth of crops. Sorghum (*Sorghum bicolor* L.) is an important multi-cut forage crop for both irrigated and un-irrigated conditions in tropical regions (Gill *et al.*,1988). It occupies maximum area among different forage crops of India, because of its wider adaptability and increasing demand for fodder to the livestock, hence its cultivation has been encouraged. For rapid growth and bumper harvest of this crop, proper fertility management is essential (Abichandani *et al.*,1973). Nitrogen, being one of the most important nutrients plays a vital role in growth and development of plant as it is the main constituent of plant protein. The optimum rate of phosphorus application is important in improving yields of most crops (Cisar *et al.*,1992).

RESPONSE OF FODDER SORGHUM TO NITROGEN

Growth and Development

Nitrogen plays a vital role in growth and development of the plants. *Singh et al.(1993)* reported that leaf area index increased significantly with N up to 80 kg/ha. However, tillers per plant responded up to 40 kg N/ha only. Mahale and Seth (1989), Patel *et al.*(1990) and Solankey *et al.*(1990) also reported that leaf area index increased significantly with N up to 80 kg/ha. The nitrogen level of 80 kg N/ha recorded significantly higher plant height and minimum days to flowering over control whereas 40 kg N/ha was found at par with higher levels during both the years of experimentation (Singh *et al.* 2005). Agarwal *et al.*, (2005) reported that plant height, stem thickness and number of functional leaves were significantly affected due to nitrogen application and exhibited increasing trend with the increasing levels of nitrogen from 0 to 150 kg/ha. Dhar *et al.*(2005) reported remarkable increase in plant height, number of green leaves, leaf and stem weight/plant when nitrogen levels increased from 40 to 80 kg/ha. Further increase in nitrogen levels did not increase the values of these parameters significantly. Similar results were recorded by Ammaji and Suryanarayan (2003). Gupta *et al.*(2008) reported that significant increase in plant height and number of tillers/ running meter row length were observed under increasing levels of nitrogen and phosphorous levels. Similar results have been reported by Sheoran and Rana (2006).

Green and Dry Fodder Yields

Green and dry fodder yields of sorghum were significantly increased with each increment in level of N from 0 to 60 kg/ha (Pankhaniya *et al.*,1997 and

Vekaria,1989). The green fodder yield of sorghum crop increased with increasing levels of nitrogen upto the maximum dose of 120 kg N/ha, (Tomar and Agarwal, 1993) and Desale *et al.(*1999). Rathod *et al.*(2002) reported the highest dry fodder yield with 120 kg N/ ha, but statistically it was at par with 80 kg N/ha. Application of nitrogen @ 80 kg/ha significantly increased green forage and dry matter yield of sorghum compared with the control and 40 kg/ha (Ram and Singh, 2001). This was due to nitrogen involvement in increasing the protoplasmic constituents and accelerating the process of cell division and elongation which in turn show luxuriant vegetative growth for higher fodder productivity. This has also been supported by Sood and Sharma (1992) and Barik *et al.*(1998). Singh *et al.*(2005) reported that the green fodder and dry matter yield significantly increased with an increase in N levels from 0 to 180 kg/ha. The increase in forage yield might be attributed to increased photosynthesis and plant meristematic activities. Increase in herbage yield with the increase in nitrogen levels may be due to combined effect of more number of plants/ unit area, taller plants and higher leaf area index (Verma *et al.*, 2005). Nitrogen application significantly affected the panicle number, panicle length, panicle girth and 1000-grain weight of sorghum. The increase in panicle length and panicle girth are governed by growth parameters which were positively related to N application (Kushwaha and Chandel 1997). Dhar *et al.*(2005) reported that green fodder and dry matter yield of sorghum increased with successive increase in nitrogen levels from 0 to 80 kg N/ha, whereas Pankhaniya *et al.* (1997) recorded the highest dry matter yield at 60 kg N/ha. Dhar *et al.*(2006) concluded that green fodder and dry matter yield increased significantly with each successive increase in N levels from 0 to 60 kg/ha, but not beyond 60 kg N/ha. Kaushik and Shakhawat (2005) exhibited that grain weight/panicle and test weight increased significantly with increase in nitrogen dose from 0 to 80 kg/ha.Verma *et al.*(2005) reported that increase in herbage was observed up to 120 kg nitrogen level and further increase in dose decreased herbage significantly. Similar results were observed by Gangwar and Singh (1992). Application of N up to 150 kg/ha increased the green forage and dry matter under first and second cuts as well as the total yield during both the years, but significant response was recorded only up to 100 kg N/ha (Vashishatha and Dwivedi,1997). These results are in confirmation with the findings of Gill *et al.* (1988). Saheb *et al.*(1997) concluded that significant increase in the total dry matter and its all components was obtained with an increase in the level of N from 0 to 150 kg/ha in both the years. This increase may be due to higher photosynthetic rate in vegetative growth phase. These results are similar with those of Jackson (1980). Abichandani *et al.* (1973) reported that with basal application of nitrogen, the yield increased significantly up to 90 kg N/ha whereas split application of 60 and 90 kg N/ha had no added advantage over the same dose applied as basal at sowing. Amongst the split application of 90 kg N/ha, 30+60 kg N decreased the yield significantly over 90 kg N/ha (basal application) on clay loam soil, while on sandy loam soil, it showed significant positive response. Dayal *et al.* (1970) and Shukla *et al*, (1967) have reported increased yield of sorghum under rainfed conditions with N application. The green and dry fodder yield of sorghum+cowpea increased significantly with increasing level of nitrogen up to 40 kg/ha (N). Nitrogen fertilization might have resulted in greater synthesis of protein and growth promoting substances and consequently increases the rate of photosynthesis by rapid rate of CO_2 utilization by leaves and increased absorption of mineral nutrients with lesser plant energy (Patel *et al.* 2008). Agarwal *et al.* (2005) reported increase in fodder yield with increasing level of nitrogen was due to its beneficial effect on plant height, stem thickness and number of green leaves.

Effect on Quality Parameters

The crude protein content in sorghum significantly increased with an increase in nitrogen level from 0 to 180 kg/ha. The increase in crude protein might be due to increased photosynthesis and meristematic activities of plant and improvement in the synthesis of protein and amino acids in the presence of adequate available N supply (Singh *et al.* 2005). Dhar *et al.* (2005) reported that crude protein yield in sorghum increases significantly with increasing level of nitrogen from 0 to 120 kg N/ha. Application of nitrogen up to 150 kg/ha increased the crude protein yield under first and second cut during both the years, but significant response was recorded only up to 100 kg/ha (Vashishatha and Dwivedi 1997). The highest crude protein content was observed with 60 kg N/ha (Patel *et al.* 2008). Quality parameters in respect of crude protein and leaf stem ratio, which are nutritional as well as palatable aspects, both were positively enhanced due to nitrogen application, (Agarwal *et al.* 2005). Crude fibre content in fodder sorghum was decreased significantly due to nitrogen application Decrease in crude fibre content with increase in nitrogen has also been reported by Tiwana *et al.* (2003). These results are in confirmation with the findings of Patel *et al. (*2008).

RESPONSE OF FODDER SORGHUM TO PHOSPHORUS

Growth and Development

Phosphorus application effectively increases the growth probably due to the cell division and more development of meristematic tissues. A consistent increase in leaf area index and yield attributes with increasing levels of P_2O_5 might be responsible for higher yield. Singh *et al.* (1993) stated that phosphorous applied @ 40 kg/ha recorded significantly higher leaf area index over lower levels of P_2O_5.

Green and Dry Fodder Yields

Pankhaniya *et al.* (1997) reported that the application of 40 kg P_2O_5/ha produced significantly higher green and dry fodder yield over control, but it was not at par with 20 kg P_2O_5/ha. Rathod *et al.* (2002) on the other hand reported that the application of 80 kg P_2O_5/ha produced significantly higher dry fodder yield during three out of seven years of experimentation and in pooled results, in the remaining years phosphorus could not produce any significant effect on dry fodder yield in sorghum. These results are co-incidence with those of Vashishatha and Dewivedi (1997). The maximum fodder yield in sorghum was obtained when phosphorus was applied @ 25 kg/ha. There was progressive increase in fodder yield up to 25 kg P_2O_5/ ha (Rashid and Iqbal, 2011). These results are also in line with those of Anees and Hassan (1996) and Gill *et al.*(1995) who emphasized adequate phosphorus fertilization to sorghum fodder on the basis of soil tests to get better yields. Dass *et al.*(1996) observed that dry matter yield of sorghum increased with the application of phosphorus at all the stages of crop growth and at boot leaf stage, response was observed up to 80 kg P_2O_5/ha. Akmal and Asim (2002) also obtained similar results regarding dry matter yield of sorghum. The economic level of nitrogen and phosphorus on the basis of response function were 74 and 33 kg/ha, respectively. Vashishatha and Dewivedi (1997) reported that increasing dose of P up to 40 kg P_2O_5/ha significantly increased total green forage yield during the second year. However, yield obtained with 40 kg and 60 kg P_2O_5/ha was found at par. Dry matter yield was increased up to 60 kg P_2O_5/ha during both the years for the first and second cut as well as the total dry matter production but the significant increase was obtained only up to 20 kg P_2O_5/ha. It was reported that the application of 40 kg P_2O_5/ha could boost the yield of green forage and dry matter yield of MP Chari forage sorghum. These results are in the close agreement with the findings of Abhichandani *et al.* (1971). Interaction effect of nitrogen and phosphorus were not significant (Singh *et al.* 1993).

Quality Parameters

Crude protein percent and total crude yield were influenced by phosphorus fertilization. Poor protein percent was recorded at 0 and 20 kg P_2O_5/ha. Significantly higher yield of crude protein was obtained at 40 kg P_2O_5/ha.

CONCLUSION

Research reports of various studies conducted in India, indicate significant favourable influence of nitrogen and phosphorus application on yield attributes, fodder and dry matter yield of sorghum. The leaf area index, plant height and days to flowering respond positively with the increase in the level of nitrogen up to 80 kg N/ha. Green and dry fodder yield of sorghum increased significantly with each increment in the level of nitrogen from 0 to 80 N kg/ha and the fodder yield increase was at par up to 120 N kg/ha but beyond this increase in nitrogen levels decrease the fodder yield significantly. Higher nitrogen application lowers the crude fibre content. Successive increase in nitrogen level improves the protein content. Application of 40 kg P_2O_5/ ha produced significantly higher green and dry matter yield. The fodder yield had an edge in clay loam over fine loamy soil. This might be due to the reason textured soils have greater water holding capacity and moisture is crucial for phosphorus diffusion availability. Dose of nitrogen and phosphorus application should be decided on the basis of soil test report to get maximum yield by reducing the cost of cultivation. Split application of nitrogen in sandy loam soils is beneficial, but harmful in clay loam soils.

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SHORT COMMUNICATIONS

Evaluation of zero - till sown wheat (*Triticum aestivum* L.) in sequence with *basmati* rice (*Oryza sativa* L.) under shallow ground water table conditions

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Zero–till technology for wheat sowing has been reported remunerative besides sustaining productivity under rice-wheat (R-W) cropping system. The rising cost of cultivation and degraded soil health have necessitated to ponder over optimization of tillage operations. Wheat sowing after *basmati* rice generally gets delayed due to shorter turn around time between rice harvesting and wheat sowing. This technology has been found to offset the losses in the productivity of wheat which are generally realized due to 10 - 15 days delayed sowing under conventional flat sown situation. It has also been reported to reduce the infestation of little seed canary grass (*Phalaris minor* Retz.), the most problematic weed in R-W cropping system. It helps in saving fuel, water and cost of production (Rs 2000/ha). It is eco-friendly and helpful in improving system productivity and soil health. There is water logging and shallow ground water table problem in several pockets of Haryana, which generally delays the wheat sowing with traditional method. Under such situations, zero tillage technology may provide some relief to the farmers. But Information on the use of such technology under shallow ground water table situation for raising wheat under R-W system at the farmers' fields is lacking. Keeping the above factors into consideration, the present study was undertaken at village Dabra in district Hisar, Haryana.

Farmers' field trials through Krishi Vigyan Kendra, Sadalpur of CCS HAU, Hisar were conducted during *rabi* season of 2005-06 to evaluate the effect of zero-tillage (ZT) in comparison to conventional tillage (CT) on the productivity of wheat. The trials were conducted at seven locations in a cluster around Dabra village of district Hisar on sandy loam to clay loam soils having pH between 7.7 to 8.5,water logging during *kharif* and shallow ground water table (2.1 to 3.3 m) in November 2005. After manual harvesting of rice variety Pusa Basmati 1 and Pusa Basmati 4 (Pusa 1121) with sickle at a height of 20-30 cm from the ground surface during 4th week of November 2005, two harrowings followed by two cultivators and one planking were done with tractor for fine seedbed preparation under conventional tillage. ZT wheat was sown directly without any tillage operation in standing stubbles using zero-till-seed-cum-fertilizer drill having inverted T-type furrow openers. Wheat cultivars PBW 343 (at 5 locations) and WH 711 (at 2 locations) were sown during the 1st week of December 2005 at 17.5 cm row spacing by using a seed rate of 125 kg/ha under ZT. Two cultivars of wheat were taken just to generate additional information on their performance under two tillage treatments. Sowing in CT plots was done by ordinary tractor drawn seed-cum-fertilizer drill during 2^{nd} week of December 2005 by using a seed rate of 125 kg/ha. Wheat crop was fertilized with recommended dose and irrigation was given as per need (Table 2) . The rainfall received during the crop season was 30.4 mm (3.2 mm in November 2005 and 27.2 mm in March 2006). For controlling grassy weeds, herbicide clodinafop (Topik 15 % W.P.) @ 60 g/ha was applied 35 days after sowing (DAS) with a manually operated knapsack sprayer attached with flat- fan-nozzles (110^0 angle) delivering a spray volume of 500 l/ha. Thereafter, 2, 4-D @ 500 g/ha was applied one week after in the same manner for controlling broadleaf weeds. Later on, the crop was raised as per recommended Package of Practices. The crop was harvested at maturity during 2^{nd} week of April 2006. The data on grain, straw and biological yields of each location were recorded at harvest and harvest index was computed. On the basis of prevailing market price of inputs used and outputs obtained, the economic returns were calculated to draw valuable inferences.

Grain yield (3600 to 4450 kg/ha), straw yield (4729 to 5575 kg/ha), biological yield (8100 to 10025 kg/ha) and harvest index (43.91 to 44.50 %) of wheat were recorded under ZT at different locations (Table 1). Harvest index was observed the maximum at location comprising WH 711 cultivar of wheat. The respective values of these parameters *i. e.* 3529 to 4350 kg/ha, 4471 to 5518 kg/ha, 8000 to 9896 kg/ha and 44.03 to 44.22%

Table 1. Effect of tillage treatments on yield and harvest index of wheat at different locations

Location	Variety	Grain yield (kg/ha)		Straw yield (kg/ha)		Biological yield (kg/ha)		Harvest index	
		ZT	CT	ZT	CT	ZT	CT	ZT	CT
1	PBW343	4200	4350	5306	5518	9506	9868	44.18	44.08
2	PBW343	3900	3850	4964	4880	8864	8730	44.00	44.10
3	PBW343	4230	4032	5403	5120	9633	9152	43.91	44.05
4	PBW343	3771	3529	4729	4471	8500	8000	44.36	44.11
5	PBW343	4450	4255	5575	5408	10025	9663	44.39	44.03
6	WH711	3600	3725	4500	4715	8100	8440	44.44	44.13
7	WH711	3800	3825	4740	4825	8540	8650	44.50	44.22
Average	-	3993	3938	5031	4991	9024	8929	44.25	44.10

Table 2. Mean economic returns and number of irrigations in wheat under zero and conventional tillage

Treatments	Cost of production (Rs/ha)	Total returns (Rs/ha)	Net returns (Rs/ha)	B :C ratio	No. of Irrigations
Z T	18162	35961	17799	1.98	3
C T	21447	35460	14013	1.65	4

were recorded under CT. ZT sown wheat, on an average, registered marginally higher grain yield (3993 kg/ha), straw yield (5031 kg/ha), biological yield (9024 kg/ha) and harvest index (44.25 %) compared to CT. ZT in wheat has earlier been reported beneficial by Lathwal *et al.* (2005), Brar and Walia (2009) and Singh *et al.*(2009).

In terms of economic evaluation, gross income (Rs 35961/ha), net income (Rs 17799/ha) and B: C ratio (1.98) due to ZT in wheat were exceeded by Rs 501/ ha, Rs 3786/ha and 0.33 over CT, respectively (Table 2). The differences were accrued upon due to higher cost of production (Rs 3285/ha) under CT. These results are in agreement with the earlier findings of Rautaray (2002) and Kumar *et al. (*2005). In general, difference of one irrigation was found between tillage treatments. Saving of irrigation water due to shallow ground water table has earlier been reported by Pannu and Sharma (2004) under CT and by Malik *et al.* (2005)under ZT.

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Yield, quality, nutrient content and uptake of chickpea (*Cicer arietinum* L.) as influenced by vermicompost, phosphorus and zinc levels

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Chickpea as a pulse crop, has an inherent capacity to fix atmospheric nitrogen and is adaptabile to a wide range of agro-ecological situations and variable management practices. Pulses are considered as the cheapest sources of protein for the vegetarian people. As per the demand of the crop, there is a possibility of raising the production per unit area by efficient and judicious use of nutrients. Vermicompost enhances the macro and micro plant nutrients, growth enhancing substances such as auxins and gibberellins and a number of beneficial microorganisms like nitrogen fixing, P-solubilizing and cellulose decomposing organisms (Sultan, 1997). Whereas most required nutrients like nitrogen, phosphorous and zinc are supplied by application of phosphorus and zinc by $ZnSo_4$, respectively.

The present investigation was carried out during *rabi* 2009-10 at Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand having the soil loamy sand in texture, low in organic carbon and nitrogen, medium in available phosphorus and high in available potassium. Twelve treatment combinations comprising of two levels of vermicompost (0 and 1.25 t/ha), three levels of phosphorus (0, 50 and 100 kg DAP/ha) and two levels of zinc sulphate ($ZnSo_4$) (0 and 25 kg/ha) were tested in a factorial randomized block design with four replications. The chickpea variety GG-1 was sown at a spacing of 30 x 10 cm on 3rd December, 2009.

The required quantity of vermicompost was applied before sowing and mixed well in the soil while DAP and $ZnSo_4$ were applied about 5 to 6 cm deep in the respective plot prior to sowing in the previously opened furrows. The seeds were sown manually 3-5 cm deep in the previously opened furrows with a recommended seed rate of 60 kg/ha. The gross and net plot sizes were 5.00 x 3.60 m and 4.00 x 2.40 m, respectively. The first irrigation was given just after sowing and two irrigations were given at flowering and pod development stages as per the requirement. Recommended plant protection meanures taken against wilt disease and pod borer. The crop was harvested on 20th March, 2011. The biometric observations were recorded from five randomly selected plants in each net plot. One hundred grains were counted from the representative sample and their weight in g was recorded as seed index for each treatment. The seed yield in kg was recorded per net plot and then calculated on hectare basis. The data on dry stover yield was obtained by deducting the seed yield from the total produce (biological yield) and recorded in kg/net plot. Later on, it was converted into hectare basis. The harvest index (%) for each treatment was worked out dividing economical yield by the biological yield. The dry weight of root nodules/ plant, taken at 45 DAS from each net plot were oven dried at 70^{0}C till the constant weight (mg) was obtained.

Representative samples of seed drawn from each net plot and oven dried at 70ºC were used for biochemical analysis. The technique employed for the biochemical analysis of the seeds for N constituent was micro Kjeldahl's digestion and distillation method (Jackson, 1973). For phosphorus and zinc contents Vanadomolybdate and Atomic Absorption Spectrophotometer (Jackson, 1973) methods were used, respectively. The nutrient uptake by the seeds was calculated by multiplying nutrient content with the seed yield (kg/ha). The protein content in seeds (%) was calculated by multiplying N content of seeds (%) with the conversion factor of 6.25.

Application of 1.25 t vermicompost/ha recorded significantly higher seed yield (1356 kg/ha) as compared to vermicompost application (1215 kg/ha) (Table 1). The increment in yield was 11.9% over no vermicompost. Similar beneficial effect of vermicompost application was observed in seed index. The constant and optimal supply of nutrients through application of vermicompost resulted in higher seed index and the seed yield. These findings are in accordance with those of Rajkhowa *et al*. (2002), Kumari and Kumari (2002) and Jat and Ahlawat (2002).

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The data on economics revealed that vermicompost application recorded higher net return of Rs. 29242/ha. However, stover yield, harvest index, dry weiht of root nodules and nitrogen and protein content in the seeds due to vermicompost application were increased significant (Tables 1 and 2). However, N uptake in the seeds was recorded significantly higher (44.15 kg/ha) with the application of vermicompost as compared to control. The differences in P content and uptake were found significant and 1.25 t vermicompost recorded significantly higher P content and uptake in the seeds (0.47% and 6.37 kg/ha, respectively) as compared to no vermicompost. This might have been due to better uptake of phosphorus from the soil. Application of vermicompost improves the phosphorus availability, which enhances various phytohormones like phosphates in soil and increases the uptake. These findings are somewhat in line with those reported by Pathak *et al.* (2003). The differences in Zn content in the seeds were found not significant. However, Zn uptake in the seeds (48.26 kg/ha) was significantly higher with 1.25 t vermicompost application as compared to no vermicompost.

Table 1. Effect of different treatments on yield, quality and economics of chickpea

Treatments	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)	Dry weight of root nodules/ planting (mg)	Seed index (g)	Protein content (%)	Net return (Rs./ha)	BCR
Vermicompost (t/ha)								
0	1215	1260	48.99	314	17.88	20.30	28955	3.56
1.25	1356	1273	51.47	322	19.25	20.31	29242	2.43
LSD (P=0.05)	131	NS	NS	NS	1.01	NS	-	-
phosphorus levels (P_2O_5 kg/ha)								
0	1174	1244	48.45	315.1	18.25	19.81	26296	2.76
23	1297	1269	50.39	316.9	18.38	20.31	29428	2.90
46	1384	1288	51.84	323.1	19.06	20.81	31526	2.96
LSD (P=0.05)	160	NS	NS	NS	NS	0.63	-	-
Zinc sulphate (kg/ha)								
0	1266	1260	49.90	318.1	18.42	20.19	29035	3.04
25	1304	1273	50.56	318.7	18.71	20.44	29132	2.74
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	-	-

Table 2. Effect of different treatments on nutrient content and uptake of chickpea

Treatments	Nitrogen (N)		Phosphorus (P)		Zinc (Zn)	
	Content (%)	Uptake (kg/ha)	Content (%)	Uptake (kg/ha)	Content (ppm)	Uptake (kg/ha)
Vermicompost (t/ha)						
0	39.45	0.45	5.44	34.92	42.69	
1.25	3.25	44.15	0.47	6.37	35.54	48.26
LSD (P=0.05)	NS	4.35	0.02	0.67	NS	4.96
phosphorus levels (P_2O_5 kg/ha)						
0	3.17	37.33	0.45	5.32	34.63	40.76
23	3.25	42.01	0.45	5.78	34.69	45.28
46	3.33	46.06	0.47	6.62	36.38	50.39
LSD (P=0.05)	0.10	5.33	NS	0.82	1.55	6.07
Zinc sulphate (kg/ha)						
0	3.23	40.99	0.45	5.71	34.92	44.47
25	3.27	42.61	0.47	6.10	35.54	46.48
LSD (P=0.05)	NS	NS	NS	NS	NS	NS

Application of 46 kg P_2O_5/ha recorded significantly higher seed yield (1384 kg/ha) than nophosphorus application and the magnitude of increase in seed yield with was 9.5 and 16.8% over control and 23 kg P_2O_5/ha treatments, respectively. Also, application of 23 kg P_2O_5/ha recorded seed yield (1297 kg/ha) at par with no phosphorus application. The result pertaining to the dry stover yield (Table 1), harvest index, dry weight of root nodules and seed index showed non-significant response to phosphorus application. Treatment with 46 kg P_2O_5/ha recorded higher net return and benefit cost ratio (BCR) of Rs. 31526/ha and 2.96, respectively.

Significantly higher the protein content (20.81%) was significantly higher under 46 kg P_2O_5/ha treatment as compared to no phosphorus application. This might have been due to fact that phosphorus promoted the root growth and thus increased the content and uptake of nitrogen which resulted in increased protein content. Malik *et al.* (2004) and Nadeem *et al.* (2004) recorded similar results.

The differences in P content in the seeds due to different phosphorus levels were found not significant. However, P uptake in the seeds (6.62 kg/ha) was significantly higher under 46 kg P_2O_5/ha treatment. The Zn content and uptake in the seeds (36.38 ppm and 50.39 kg/ha, respectively) were observed to be significantly higher under 46 P_2O_5/ha treatment as compared to other levels of phosphorus.

Application of zinc did not influence the yields, protein content, nutrient content and uptake, harvest index, seed index and dry weight of nodules in chickpes.

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Relative tolerance of kabuli chickpea (*Cicer arietinum* L.) genotypes against drought

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Chickpea commonly known as gram or Bengal gram is the third most important pulse crop in the world. India is the world's largest producer of chickpea with an area of 8.25 mha recording a productivity of 855 kg/ ha (Jayalaxmi *et al*. 2011). It is a rich supplement to cereal based diet, especially to the poor in the developing countries, where people can not afford animal protein (or are vegetarian). *Kabuli* chickpea being rich in protein and used for culinary purposes has good potential for export as well. An important limiting factor in chickpea yield is the low moisture availability, since it is generally grown under conserved soil moisture condition. Thus, drought stress is the most common adverse environmental condition that can seriously reduce crop productivity. Hence, selection of genotypes tolerant to drought stress would be the most appropriate to improve productivity and can prove a boon to improve the economy of poor farmers of dryland areas of the country.

The experiment was conducted during *rabi* season of 2003-04 in concrete micro plots (6 X 1 X 1.5 m) filled with dunal sand located at Research Farm of CCS Haryana Agricultural University, Hisar (at 29º10'N latitude and 75º46'E longitude with elevation of 215.2 m above mean sea level). The experiment was laid out in split plot design with four replications. Experiment consisted of three environments of moisture in main plot i.e. severe stress (no post sowing irrigation), mild stress (one irrigation at 70 DAS) and no stress (two irrigations at 70 and 110 DAS) with five genotypes in sub plots namely HK00-300, HK99-214, HK98-155, HK00-290 and HK-1. The crop was raised with recommended Package of Practices.

The five representative plants in each replication were sampled from each treatment for recording root and shoot growths in terms of biomass and length at 120 DAS. The height of shoot and depth of roots was measured from soil surface to growing point of main shoot/tip of root with meter rod. Leaf turgor potential (Y_p) was calculated from leaf water potential (Y_L) and leaf osmotic potential (Yp) as (Y_L = Yp + Y_p). Leaf osmotic potential was measured by taking three or four leaves from the same plant from which the leaf was taken to measure relative water content (Weatherley, 1965). The air tight syringes were used to keep the leaves samples and placed in freezer at -15^{0}C. The sap from these leaf tissues was extracted on filter paper discs and osmotic potential was measured using 5100-B vapor pressure osmometer. Specific leaf weight, as a measure of leaf thickness, was computed by dividing leaf weight by leaf area. The root : shoot ratio was computed on both the length and weight basis by dividing the weight and length of root by corresponding weight and length of shoot. The mobilization of assimilates from roots, leaves and stem to developing sink was computed from the per cent reduction in biomass at 120 DAS till maturity. Yield based drought tolerance indices:stress intensity, mean productivity,geometric mean productivity (GMP) and stress tolerance index (STI) were calculated according to Fernandez (1993). Osmotic adjustment was computed as per Blum (1989).

Root depth was significantly lower in irrigated control than mild stress and severe stresses, because the roots going to deeper depth of soil profile tracing water seem to be the reason for increase in root depth in stress environment (Table 1). Among the genotypes, root depth was found highest in HK 99-214 followed by HK00-300 and HK98-155, which were statistically at par and differed significantly from HK00-290 and HK-1.

Shoot height was significantly higher in irrigated control as compared to mild and severe stress. The reduction in shoot growth under stress environment was because of limited water availability, which is most essential for the basic processes of growth, *viz*. photosynthesis and for the maintenance of cell turger potential which is essential for cell enlargement and cell division. The differences in shoot height of mild and severe stresses were also significant at 120 DAS. Among the genotypes, HK00-300 and HK98-155 were the tallest with non- significant difference. But these were significantly taller than all other genotypes. Similarly genotypes HK-1 and HK99-214 were small statured with non-significant difference between them. However, their shoot heights were significantly lower than all other genotypes.

Table 1. Morpho-physiological drought tolerance parameters and yield of chickpea genotypes under different moisture stress levels

Treatments	Root depth (cm)	Plant height (cm)	Root dry weight (g)	Shoot dry weight (g)	Root : Shoot		Specific leaf weight (mg/cm2)	Per cent mobilization to sink			Seed yield (kg/ha)
					Length basis	Dry weight basis		leaf	Stem	Root	
Severe stress	91.9	63.7	4.00	14.95	1.44	0.28	8.72	5.28 (0.29)	0.50 (0.07)	11.75 (0.47)	904
Mild stress	86.7	67.1	3.90	15.61	1.29	0.25	8.10	2.66 (0.15)	0.10 (0.07)	4.61 (0.18)	1028
No stress	85.4	70.4	5.13	18.63	1.21	0.26	7.94	1.41 (0.16)	-6.69 (-0.60)	0.39(0.02)	2007
L. S. D. (P=0.05)	6.3	1.3	0.34	0.35	0.11	NS	0.41	0.39	0.77	3.21	27
Genotypes											
HK 00-300	91.3	70.0	4.29	17.39	1.30	0.24	8.22	2.46 (0.20)	-0.51 (-0.06)	5.13 (0.22)	1113
HK 99-214	92.3	63.3	4.87	15.83	1.45	0.31	7.35	3.57 (0.21)	-4.68 (-0.31)	4.52 (0.22)	1303
HK 98-155	90.7	71.4	4.01	16.94	1.27	0.23	9.21	4.61 (0.29)	-2.77 (-0.25)	0.24 (0.01)	1475
HK 00-290	79.5	67.7	4.46	16.49	1.17	0.27	7.83	2.20 (0.14)	0.70 (0.08)	13.23 (0.59)	1311
HK-1	86.0	62.9	4.09	15.32	1.36	0.26	8.51	2.74 (0.17)	-2.81 (-0.25)	2.44 (0.10)	1363
L. S. D. (P=0.05)	3.7	2.2	0.34	0.49	0.06	0.03	0.62	0.40	0.72	1.85	48

* Values in parenthesis are absolute dry weight in g.

Root : Shoot ratio on length basis was highest under severe stress and lowest under irrigated control with a significant difference. The difference in root: shoot ratio between mild and severe stresses were non-significant. These results are in conformity with Rahman and Uddin (2000). Among genotypes, root:shoot ratio was observed to be the highest in HK 99-214 followed by HK-1 and the lowest in HK00-290. The difference in HK 99-214 and HK-1 were statistically at par. The ratio was significantly lower in HK00-290 than all other genotypes.

The root and shoot dry weights were highest in unstressed irrigated environment, which was significantly higher than mild and severely stressed environments. The differences in root weight in mildly and severely stressed environments were non- significant but for shoot weight this difference was significant. Root weight was the highest in genotype HK 99-214 followed by HK00-290 and it was lowest in HK98-155. The root weight in genotype HK 98-214 was significantly higher than all other genotypes. However, the root weight of HK98-155 was statistically at par with HK-1 and HK00-300.

The highest shoot dry weight was observed in HK00-300 followed by HK98-155 and HK00-290, while the minimum in HK-1. The significant positive relationship of root weight with yield (r=0.71) and shoot weight with yield (r=0.76) indicate that strong root and shoot systems are required for higher yield.

Moisture stress treatment could not create significant variation in the ratio of root and shoot biomass. However, severe stress increased the root: shoot weight ratio in favor of roots. Among the genotypes, root:shoot ratio was highest in HK99-214 which was significantly higher than all other genotypes. It was lowest in HK98-155 with non-significant difference between HK00-290 and HK-1.

Specific leaf weight (SLW) was significantly higher under severe stress condition than mildly stressed environment and irrigated control which were statistically at par. SLW is an indicator of leaf thickness and is an adaptive mechanism to sustain stress by reducing the leaf area and by ceased cell enlargement and cell division. Therefore, under limited water availability, leaves become more thicker and increase the SLW. Among the genotypes, SLW was recorded the maximum in HK98-155 followed by HK-1 and it was the minimum in HK99-214. The SLW of HK98-155 differed significantly over other tested genotypes because this genotype is superior and efficient in conversion of radiant energy into growth. These results are in conformity with those of Sharma *et al.(*2007).

The mobilization of assimilates from vegetative plant parts namely root, leaf and stem to pod and seed indicated that it was higher from root and leaf than stem. The increased moisture stress increased the mobilization but in irrigated control there was no mobilization from the stem. Similar results were also reported by Guhey and Trivedi (2001). Among the genotypes, the significantly higher mobilization from the leaf was observed in HK98-155 than all other genotypes. The mobilization from the leaves of HK00-290 was the least. All other genotypes did not show any mobilization from stem except HK00-290.

Relative water content (RWC) decreased at 2 P.M. than recorded at 10 A.M. in the morning (Table 2). The lower RWC values in afternoon than in morning in all the treatments might be due to increased atmospheric demands by increased radiation load, increase in temperature and vapour pressure deficit, where plant have to lose more water and plant lagged behind in absorption of water from soil profile than lost through transpiration Pannu *et al.*(1993). The increase in moisture stress from irrigated control to mild and severe stress reduced the RWC significantly due to the variability in soil profile supplying capacity on the day of observation among the various treatments. The highest RWC was observed in HK00-290 while, the lowest in HK-1.

The increase in moisture stress from irrigated control to mild and severe stress reduced the osmotic potential (Yp) significantly. Among the genotypes, the highest Yp was recorded in HK00-300 which was statistically at par with HK00-290 and it was the lowest in HK99-214 with significant differences.

Osmotic adjustment is important physiological trait which helps the plant to continue growth process in spite of severe moisture stress due to low soil water by maintaining leaf turgor potential (Y_p) and accumulating osmolytes reducing osmotic potential (Y_p). The highest osmotic adjustment was recorded in genotype HK00-290 closely followed by HK98-155 and HK-1. It was the lowest in HK00-300. Similar genotypic variations had been observed by Blum (1989). The osmotic adjustment had a significant positive association with seed yield (r=0.83).

The yield based stress indices and stress intensity of 0.55 value (Table 3) showed that the moisture stress was of moderate level and under this level of stress. Genotype HK98-155 was the most drought tolerant

Table 2. Effect of moisture stress on relative water content, osmotic potential (Yp) and osmotic adjustment in chickpea genotypes

Treatments	Relative water content (%)		Osmotic potential (bar)		Osmotic Adjustment (bar)
Stress environments	10 am	2 pm	10 am	2 pm	-
Severe stress	64.7	55.5	-26.3	-27.4	-
Mild stress	68.1	59.3	-24.2	-25.4	-
No stress	72.5	66.7	-14.5	-16.7	-
L. S. D. (P=0.05)	4.3	2.1	0.4	0.7	-
Genotypes					
HK 00-300	69.3	59.3	-20.3	-22.5	1.52
HK 99-214	68.9	56.9	-22.2	-22.8	1.71
HK 98-155	66.4	62.7	-21.5	-24.3	2.08
HK 00-290	73.5	64.1	-21.3	-23.5	2.10
HK-1	63.9	59.4	-22.9	-22.7	2.07
L. S. D. (P=0.05)	3.5	3.3	1.1	0.9	-

Table 3. Yield based drought tolerance indices of chickpea genotypes

Genotypes	Drought tolerance indices		
	Mean productivity (kg/ha)	Geometric mean productivity (kg/ha)	Stress tolerance index
HK00-300	1229	1154	0.33
HK99-214	1455	1333	0.44
HK98-155	1642	1526	0.58
HK00-290	1439	1328	0.44
HK-1	1515	1395	0.48

Stress intensity = 0.55

followed by HK-1 because of its highest mean productivity, GMP and STI. Whereas, genotype HK00-300 was drought susceptible due to its lowest mean productivity, GMP and STI. These results corroborate the findings of Pannu *et al.*(1993).

The moisture stress at reproductive stage of chickpea reduced the seed yield to the extent of 54.9 per cent (Table 1). Seed yield (2007 kg/ha) was significantly higher under irrigated control (no stress) than recorded under stressed environments. Genotype HK98-155 yielded highest followed by HK-1 due to better drought tolerance. Seed yield was reduced with the increase in moisture stress. The mild stress reduced the seed yield drastically to almost half of irrigated control in all the genotypes. But, under severe stress there was further reduction in yield but the quantum of reduction was low. A positive point in favor of this genotype seems to be its shorter maturity duration which may have helped it to escape from the more severe water deficit in the soil profile. This fact can be supported by highly significant association of seed yield with mean productivity (r=0.99), GMP (r=0.99) and STI (r=0.83). These results are in conformity with Kumar *et al.* (2006).

The differential behavior of different genotypes to water stress may be attributed to their variable genetic makeup and impaired physiological mechanism of plants carried out with available water. Hence, genotype HK 98-155 holds good promise to perform better under all the tested environments than other genotypes.

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Performance of American cotton genotypes at farmers' fields

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Several insect-pests, diseases, nematodes and weeds simultaneously attack, usurp and threaten the cultivation of *hirsutum* cotton crop during the last decade of the 20th century. It could not be protected against bollworm complex in spite of 8-10 costly sprays of insecticides at week's interval. The farmers of the United States of America harvested increased seed cotton yields, gained higher profits and reduced pesticide use due to cultivation of transgenic *Bt* cotton hybrids (Carlson *et al*., 1998). *Bt* cotton was introduced for the first time in India during 2002-2003. The Central Government approved transgenic *Bt* cotton hybrids for general cultivation in whole of the North Zone of India for playing a vital role in pest management. It was introduced in the cotton belt i. e. Hisar, Fatehabad and Sirsa districts of Haryana in 2005 for managing American bollworm (*Helicoverpa armigera* (Hubner) with a view to higher seed cotton yield and economic gains to the farmers and reduce the pesticide consumption. It was an innovative technology. Therefore, present investigation on yield performance and economic viability of four genotypes of *hirsutum* cotton *viz*., 2 released non *Bt* hybrid, 1 non *Bt* variety and 1 *Bt* cotton hybrid in comparison with existing non *Bt* recommended varieties was undertaken at farmers field in different villages of Hisar district.

Demonstrations at farmers fields through Krishi Vigyan Kendra, Sadalpur of CCSHAU, Hisar were conducted on American cotton (*G. hirsutum* L.) at 34 locations during *Kharif* 2005 season to evaluate the productivity and profitability of American genotypes i.e. 2 non *Bt* hybrids HHH 287 and LHH 144, 1 non *Bt* variety H1117 and 1 *Bt* cotton hybrid MRC 6301 under improved production technology (IPT) in comparison with local check(LC i. e. H 1098, HS 6, RST-9) under conventional farmers practices (FP) under semi- arid environment of Hisar district. The soils of demonstration sites were alluvial sandy loam to loam in texture, poor in organic carbon, low in nitrogen, medium in phosphorus and medium to high in potash with slightly alkaline pH ranging from 7.6 to 8.2 and good moisture holding capacity. The plot size for each demonstration was kept as 0.2 ha under 2 non *Bt* cotton hybrids and 1 *Bt* cotton hybrid whereas 0.4 ha under non *Bt* cotton variety. In demonstrations, the identified farmers were provided quality seeds of HHH 287, LHH 144, H1117 and transgenic *Bt* cotton hybrids MRC 6301 and need based pesticides. Heavy pre-sowing irrigation was applied. Line sowing of both non *Bt* and *Bt* cotton hybrids on well prepared, weed- stubble free and *vattar* fields was done in E-W direction in evening hours at 67.5 x 60 cm spacing and that of non *Bt* at 67.5 x 30 cm spacing during 19th Standard Week (2nd week of May) by pora/ dibbling method by using water soaked and treated seeds @3.75, 3.75, 15.0 and 2.85 kg/ha, respectively. All the recommended Package of Practices were timely followed in the demonstration plots. In comparison, each of the selected farmers raised existing variety (LC) in 0.4 ha area by using his own practices. The farmers used non-recommended insecticides either at low or high dose both for sucking and boll worm pests at ETL with about 50% usage of spray solution. Five lines of refugia in *Bt* cotton was sown on all the four sides of each demonstration. About 487 mm rainfall was received in the area in 26 rainy days at 3 stages viz., sowing to early growth stage (97.3 mm, 6 days), flowering to fruiting stage (386.6 mm, 19 days) and boll setting to picking stage (3.2 mm, 1 day). The crop experienced a dry spell of about 4 weeks in the first week of August to first week of September. At this stage, the farmers having canal water applied a light irrigation to the crop. Excluding pre-sowing irrigation, the farmers applied two need based irrigations in the months of June and August/September. The harvesting of crop was started at physiological maturity in the first week of October and seed cotton was picked up in 3 pickings at an interval of about two weeks up to 45th Standard Week (2nd week of November). The total seed cotton yields were obtained and data on output and inputs/ha were collected both from frontline demonstrations under IPT and LC with FP. The yield gap, cost and returns were calculated in such a way as suggested by Prasad *et al.* (1993).

The following formulae were used to estimate the gaps and index:

a. Extension gap (kg/ha)=Demonstration yield (Di)-Local check yield (Li)
b. Technology gap (kg/ha)=Potential yield (Pi)-Demonstration yield (Di)
c. Technology Index (%)=((Pi-Di)/Pi)*100
d. Additional returns (Rs/ha)=(Di-Li)* sale price
e. Effective gain(Rs/ha)=Additional returns-additional cost
f. Incremental benefit (Rs/Re)=Additional returns/additional cost of cash inputs

The seed cotton yield of non *Bt* hybrid HHH 287 with IPT was found ranging from 1800 to 2000kg/ha where as that of LHH 144 in the range of 1700 to 1890 kg / ha and 24% higher over local check with FP. The seed cotton yield of transgenic *Bt* cotton hybrid MRC 6301 ranged from 1910 to 2220 kg/ha with an averaged seed cotton 2050 kg/ha, 41.3% higher over local check (Table 1). Non *Bt* variety H117 under IPT recorded 12.5% higher seed cotton yield over LC with FP. However, the realized yields were lower than the potential yields of the genotypes. Enhanced seed cotton yields might have been due to IPT in the form of recommended Package of Practices including quality seeds, proper plant protection, moisture conservation, timely weed removal and insect-pest control measures. Enhanced seed cotton yields due to IPT have been reported by Bambawale *et al.* (2004), Giri and Kapse (2007) and Mehta *et al.* (2009).

Extension gap was calculated as yield difference between IPT and LC. On an average of 34 demonstrations, the extension gap was recorded as 370 kg/ha. This gap could be attributed to poor performance of local checks under FP. Such gap revealed about the essence of IPT adopted in front line demonstrations. The lower extension gap reflected good extension activities. The gap could have been lowered down further by strengthening extension activities, training and education of the farmers for adoption of scientific crop production technology.

The technology gap ranged from 1150 to 2080 kg/ha. There was inverse relation between technology gap and extension gap. The higher technology gap did

Table1. Genotypes, number, seed cotton yield and gap analysis of front line demonstrations on American cotton

Genotype	Seed cotton yield (kg/ha)		Potential yield (kg/ha)	Increase in seed cotton yield over LC	Extension gap (kg/ha)	Technology gap (kg/ha)	Technology index (%)
	Genotype+ IPT range	LC+FP					
HHH287	1800 to 1820	1460	3200	24.0	350	1390	43.4
LHH144	1750 to 1890	1450	3100	24.1	350	1300	41.9
Average	1805	1455	3150	24.0	350	1345	42.6
MRC6301	1910 to 2220	1450	3200	41.3	600	1150	36.0
H1117	1530 to 1720	1440	3700	12.5	180	2080	56.3

Table 2. Economic evaluation of frontline demonstrations under IPT vis-à-vis LC (FP) on American cotton

Genotype	Cost of cash inputs (Rs/ha)		Sale price of seed cotton (Rs./q)	Total returns (Rs/ha)		Additional cost in demons-tration (Rs./ha)	Additional returns in demons-tration (Rs./ha)	Effective gain (Rs./ha)	IBCR (Rs./Re)
	IPT	LC		IPT	LC				
HHH287	8496	6300	1962	35512	28645	2196	6867	4617	3.12
LHH144	8460	6300	1962	35316	28449	2160	6867	4707	3.18
Average	8478	6300	1962	35414	28547	2178	6867	4662	3.15
MRC6301	9360	6300	1962	40220	28449	3060	11771	8711	3.84
H1117	7380	6300	1962	31784	28253	1080	3531	2451	3.26

not show the existence of IPT under real farming situation. Though the frontline demonstrations were conducted under the supervision of experts, yet there was still a wide gap of 1480 kg/ha between crops potential yield and frontline demonstration yield. This was due to abiotic stresses, differential soil fertility status, resource use patterns and locations specific management problems. The technology index, a yardstick of adoption of IPT, was higher (56.3 %), medium (43.4%), lower 36.0 % and average (44.4%) in accordance with the technology gap. Its lower value, as a function of technology gap indicated the higher perfection of IPT.

Both seed cotton yield variations and deviations in the sale price of kapas in the months of November, 2005 to January, 2006 influenced the total monetary returns (Table 2). The higher seed cotton yield gave higher returns. Additional returns of Rs. 7259/ha and effective gain of Rs. 5135/ha were recorded. On an average , incurring Rs. 2124/ ha additionally under IPT resulted in Rs. 7259 / ha additional returns over the LC. The highest effective gain of Rs. 8711/ ha was recorded under MRC 6301 Bt hybrid whereas an overall average was Rs. 5135/ha. The incremental benefit cost ratio (IBCR) ranged from 3.12 to 3.84 averaging 3.35. These observations confirm the earlier findings of Garg *et al.* (2004), Patil *et al.* (2004).

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Performance of newly evolved hybrid and variety of *desi* cotton at farmers' field

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Desi cotton (*Gossypium arboreum* L.) though grown in only 2% of total area under cotton in Haryana. Comparing American cotton, it has high degree of immunity against insect-pests, dreaded CLCuV disease and tolerance to various stresses. Continuation in genetic improvement is very essential for meeting the ever increasing demand of fiber and feed. New hybrids and variety of desi cotton have been evolved for agro-ecological conditions of cotton belt of Haryana. The information regarding productivity and profitability of newly evolved variety HD-324, hybrid CICR-2 and old hybrid AAH-1 for commercial cultivation of desi cotton under improved production technology (IPT) in comparison to prevailing local varieties under conventional farmers practices (FP) was not available.

Demonstrations at farmers' fields through Krishi Vigyan Kendra, Sadalpur of CCS HAU, Hisar were conducted on desi cotton (*G. arboreum* L.) at 46 locations during *kharif* 2005 to evaluate the productivity and profitability of old hybrid AAH-1 with 17 demonstrations and newly released hybrid CICR-2 with 10 demonstrations and variety HD-324 with 19 demonstrations under improved production technology (IPT) in comparison with local check (LC i.e. HD-123, HD-107, RG-8/own seed) under conventional farmer practices (FP) in the semi-arid environment of Hisar district, Haryana. The soils of demonstration sites were alluvial sandy loam to loam in texture, poor in organic carbon, low in nitrogen, medium in phosphorus and medium to high in potash with slightly alkaline pH ranging from 7.7 to 8.1 and good moisture holding capacity. The plot size for each demonstration was kept as 0.4 ha. In demonstrations, the identified farmers were provided quality seeds of AAH-1, HD-324 and CICR- 2 and need based pesticides. Heavy pre-sowing irrigation was applied. Line sowing of desi cotton hybrid AAH-1 on well prepared, weed and stubble free fields was done in E-W direction in evening hours at 67.5 x 30 cm spacing on 19-23 April and similarly that of variety HD-324 on 20-24 April whereas that of CICR- 2 on 13-15 May by pora/ dibbling method by using water soaked and treated seeds @ 3.0, 12.5 and 3.0 kg/ha, respectively. All the recommended package of practices was timely performed in demonstration plots. In comparison, each of the selected farmer raised existing *desi* cotton variety (LC) in 0.4 ha area by using his own practices. About 487 mm rainfall was received in the area in 26 days at three stages viz., sowing to early growth stage (97.3 mm, 6 days), flowering to fruiting stage (386.6 mm, 19 days) and boll setting to picking stage (3.2 mm, 1 day). The crop experienced a dry spell of about 4 weeks after 1st week of August to 1st week of September, hence, slight to mild moisture stress during after - noon hours was observed during this period. At this stage, the farmers having canal water, applied a light irrigation to the crop. The harvesting of crop was timely started at maturity in 2nd fortnight of September and seed cotton was picked up in 3 pickings at an interval of 8-10 days. The total seed cotton yields were obtained and data on output and inputs/ha were collected both from frontline demonstrations under IPT and LC with FP. The yield gap, cost and returns were calculated as suggested by Prasad *et al.* (1993).

The following formulae were used to estimate the gaps and index:

a. Extension gap (kg/ha)= Demonstration yield (Di)-Local check Yield (Li)

b. Technology gap (kg/ha) = Potential yield (Pi)-Demonstration yield (Di)

c. Technology index (%) = ((Pi-Di)/ Pi) x 100

d. Additional returns (Rs/ha) = (Di -Li) x Sale price

e. Effective gain (Rs/ha)=Additional returns-Additional cost

f. Incremental benefit = Additional returns/Additional cost of cash inputs cost ratio (IBCR)

Under IPT, the seed cotton yield of both the hybrids i.e. AAH-1 (1944 kg/ha) and CICR-2 (1680 kg/ha) as well as their average (1812 kg/ha) and variety HD-324 (1614 kg/ha) was found 20.0 and 8.0% higher over the local checks, respectively. Enhanced seed cotton yield might have been due to IPT in the form of recommended package of practices including quality seed, proper plant population, moisture conservation, timely weed removal and insect-pests control measures. Enhancement in seed cotton yields due to IPT have been reported by Katkar *et al.* (2005) and Giri and Gore (2006).

Extension gap was calculated as yield

differences between IPT and LC. On an average of 27 demonstrations, the extension gap was recorded as 302 kg/ha which could be attributed to poor performance of local checks under FP. On the basis of 19 demonstrations, an extension gap of 119 kg/ha was found under newly released variety HD-324. Such gap revealed about the essence of IPT adopted in frontline demonstrations. The lower extension gap reflected good extension activities. The gap could have been lowered down further by strengthening extension activities.

Under hybrids, the technology gap ranged from 1420 to 2856 kg/ha under hybrids. There was inverse relation between technology gap and extension gap. The higher technology gap did not show the existence of IPT under real farming situation. Though the frontline demonstrations were conducted under the supervision of experts, yet there was still a wide gap of 2138 kg/ha and 1186 kg/ha with respect to potential yield of hybrids and variety under test in front line demonstration. This was due to abiotic stresses, differential soil fertility status, resource use patterns and location specific management problems. The technology index, a yard stick of adoption of IPT, was 59.5% in AAH-1 and 45.8 % in CICR-2 and average (52.7%) in accordance with the technology gap. It was found to be 42.3% under variety HD-324. Its lower value, as a function of technology gap, indicated the higher perfection of IPT.

The higher seed cotton yields gave higher returns (Table 2). Average additional returns of Rs 5666/ha and effective gain of Rs 3891 /ha were recorded under both the hybrids. On an average, incurring Rs 1775/ha additionally under IPT resulted in Rs.5666/ha additional returns over the LC. This amount of Rs.1775 /ha is so less that even a small and marginal farmer can afford it easily. Additional return of Rs. 2238/ha and effective gain of Rs 1618/ha were recorded under variety HD -324.The effective gain of Rs. 4217/ha and Rs. 3565/ha were recorded under AAH-1 and CICR-2, respectively with an average of Rs. 3891/ha .The incremental benefit cost ratio (IBCR) ranged from 3.04 (CICR-2) to 3.34 (AAH-1) with an average of 3.19. Its value was found to be 3.61 under variety HD-324. The rural social milieu, poor marketing and credit support along with inadequate storage facilities were also noticed and discussed with the farmers as obstacles in effective transfer of IPT.

Table 1. Mean seed cotton yield and gap analysis of frontline demonstrations on desi cotton

Genotype	Seed cotton yield (kg/ha)		Potential yield (kg/ha)	Increase in seed cotton yield over LC (%)	Extension gap (kg/ha)	Technology gap (kg/ha)	Technology index (%)
	IPT /Range	LC+FP / Range					
AAH-1	1944/1390-2540	1620/1290-1860	4800	20.0	324	2856	59.5
CICR-2	1680/1290-2100	1400/1210-1700	3100	20.0	280	1420	45.8
Average	1812/1340-2320	1510/1250-1780	3950	20.0	302	2138	52.7
HD 324	1614/1260-1980	1495/1170-1800	2800	8.0	119	1186	42.3

Table 2. Economic evaluation of frontline demonstration under IPT vis a vis LC with farmers practices on desi cotton

Genotype	Cost of cash inputs (Rs./ha)		Sale price of seed cotton (Rs./qtl)	Total returns* (Rs./ha)		Additional cost in demonstration (Rs./ha)	Additional returns in demonstration (Rs./ha)	Effective gain (Rs./ha)	Increment benefit ratio (IBCR)
	IPT	LC		IPT	LC				
AAH-1	5000	3200	1836	37768	31751	1800	6017	4217	3.34
CICR-2	4950	3200	1836	32595	27280	1750	5315	3565	3.04
Average	4975	3200	1836	35181	29515	1775	5666	3891	3.19
HD-324	3820	3200	1836	31308	29070	620	2238	1618	3.61

*Inclusive of income from sale of sticks

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Effect of row ratios and fertility levels on productivity of pearl millet (*Pennisetum glaucum* L.) – green gram intercropping system under middle Gujarat conditions

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Pearl millet [Pennisetum glaucum (L.) *Br. Emend, Stuntz*] is an important dual purpose crop as its grain is used for human consumption and fodder as cattle feed. Shortage of pulses in the country have focused the attention on intercropping systems, which have also the capacity to improve nutrient ststus of the soil. Intercropping of pearl millet with legumes increases the productivity per unit area and avoids the risk of failure of crops. Fertilizer management is one of the important cost effective factors known to augment the crop production. Hence, with the overall view of maintaining soil fertility and economizing fertilizer use, inclusion of legumes in any intercropping system has become imperative.

A field experiment was conducted during *summer,* 2011 at B. A. College of Agriculture, Anand Agricultural University, Anand. The experimental soil was low in available nitrogen, medium in available phosphorus and high in available potassium. The experiment was laid out in factorial randomized block design with combinations of four intercropping treatments (pearl millet sole, pearl millet+green gram 1 : 1, pearl millet+ green gram 2 : 1 and pearl millet+green gram 1 : 2) and three fertility levels (50, 75 and 100% of RDF) replicated four times. The GHB-558 and Meha were used as test varieties for pearl millet and green gram crops, respectively. Sole planting of pearl millet was done at 45 x 10 cm. Fertilizer application was done as per treatments i. e. 50, 75% and 100% of RDF (RDF is 120-60-0 and 20-40-0 kg NPK/ha for pearl millet and green gram, respectively). Sowing was done on 1^{st} March and harvesting of pearl millet and green gram was done on 25^{th} and 30^{th} May, 2011, respectively.

Pearl millet sole recorded significantly highest grain (3758 kg/ha) and stover (7280 kg/ha) yield than other intercropping treatments (Table 1). Significantly lowest grain (2344 kg/ha) and stover (4428 kg/ha) yields were recorded under pearl millet+ green gram at 1 : 2 row ratio. The lower yield under this treatment may be due to lower plant population and higher competition offered by intercrop for resources like space, plant nutrients, moisture and incoming solar radiation. The results corroborate with the finding of Gadhia and Khanpara (1994), Baldevram *et al*. (2005), Kumar *et al*. (2006) and Choudhary (2009).

Significantly the highest seed (592 kg/ha) and stover (972 kg/ha) yields of green gram were recorded under treatment I_4 (pearl millet+green gram 1 : 2). The lowest seed (377 kg/ha) and stover (562 kg/ha) yields of green gram were produced under pearl millet+green gram 2 : 1 treatment. This lower yield might be due to decrease in plant density when grown as intercrop with pearl millet and higher competition among pearl millet and intercrop for soil moisture, plant nutrient, space and sunlight responsible for higher photosynthetis rate resulting in lower accumulation of dry matter per plant in comparison to sole crop. These results were supported by Baldevram *et. al.* (2005), Kumar *et al.* (2006) and Choudhary (2009).

Significantly the highest pearl millet grain equivalent yield was produced when pearl millet was intercropped with green gram at 1 : 2 row ratio (Table 1). This might be due to additional advantage of intercrop yield due to better complementary relationship in the system. Pearl millet equvalent yield was also significantly higher in 1 : 1 and 2 : 1 intercropping ratios than that of sole pearl millet. These findings are in conformity with those reported by Shrivastava (1996), Ramulu *et al.* (1998), Baldevram *et al.* (2005), Kumar *et al.* (2006) and Choudhary (2009) and Hooda *et al.* (2004).

All intercropping treatments recorded land equivalent ratio (LER) of more than 1.00 indicating greater biological efficiency of the intercropping systems (Table 1). The highest value of LER (1.23) was observed in the treatment I_4 (pearl millet+green gram 1 : 2), which also established its superiority than intercropping systems with 1 : 1 and 2 : 1 ratios. Relative crowding co-efficient (RCC) values for all the treatments of pearl millet intercropped with legumes was greater than pearl millet sole indicating their yield advantage due to mutual cooperation. Likewise, the RCC was highest (3.47) in the row ratio 1 : 2 of pearl millet+green gram followed

Table 1. Effect of row ratios and fertility levels on grain and stover yields of pearl millet and green gram

Treatment	Pearl miller		Green gram		Pearl millet grain equivalent yield (kg/ha)	Land Equivalent ratio	Relative crowd co-efficient	Aggere-sivity
	Grain yield (kg/ha)	Stover yield (kg/ha)	Grain yield (kg/ha)	Stover yield (kg/ha)				
Intercropping (Row ratios)								
I_1 (Sole)	3758	7280	-	-	3758	1.00	-	-
I_2 (1 : 1)	2506	5178	492	821	5458	1.17	2.04	0.16
I_3 (2 : 1)	2949	6071	377	562	5217	1.17	1.84	-0.008
I_4 (1 : 2)	2344	4428	592	972	5901	1.23	3.47	0.19
LSD (P=0.05)	226	613	30	83	294	0.07	-	-
Fertility levels (kg/ha)								
F_1 (50% RDF)	2695	5307	444	746	4696	1.07	1.87	0.15
F_2 (75% RDF)	2881	5738	495	770	5111	1.15	2.40	0.16
F_3 (100%RDF)	3092	6174	522	839	5442	1.20	3.07	0.18
LSD (P=0.05)	196	531	30	83	254	0.06	-	-

by RCC value of 2.04 under pearl millet+green gram in 1 : 1 ratio (Table 1). Pearl millet in combination with green gram in the row ratio of 1:2 was more competitive than other intercropping systems as this proportion had higher aggressivity value.

Application of 100% RDF gave significantly the highest grain yield (3092 kg/ha) of pearl millet among the different fertility levels (Table 1). Whereas, 75 and 50% RDF remained at par with each other. It might be due to the fact that higher fertilization made the plants more efficient in photosynthetic activity and thereby enhancing carbohydrate metabolism in the plants.

Application of 100% RDF and 75% RDF gave at par results for stover yield of pearl millet. Application of 75% RDF and 50% RDF also gave at par results with each other for the same character, but 100% RDF gave significantly higher stover yield than 50% RDF. This results matched with the findings of Hooda *et al.* (2004). The differences due to fertility levels were found significant for LER (Table 1) and 100% RDF recorded the highest value of LER than other fertility levels. Similarly, RCC (3.07) and Aggresivity (0.18) were the highest with 100% RDF, followed by 75% RDF.

The interaction effect between intercropping and fertility levels was found significant for grain yield of pearl millet (Table 2). Sole crop of pearl millet with 100% RDF gave significantly the highest grain yield (4046 kg/ha). Treatment of pearl millet+green gram 2 : 1 with 100% RDF gave higher yield of 3047 kg/ha than other intercropping ratios. The lowest grain yield of pearl millet was obtained in I_4 (pearl millet+green gram 1 : 2) with 50% RDF (2065 kg/ha).

Table 2. Grain yield of pearl millet (kg/ha) as influenced by interaction of row ratios and different fertility levels

Intercropping	Fertility levels		
	F_1 (50% RDF)	F_2 (75% RDF)	F_3 (100% RDF)
I_1 (Sole)	3546.50	3681.50	4046.50
I_2 (1:1)	2294.75	2598.75	2625.75
I_3 (2:1)	2873.75	2927.50	3047.50
I_4 (1:2)	2065.75	2318.75	2648.25
LSD (P=0.05)		391.91	

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Path coefficient studies in pearl millet hybrids under irrigated conditions in southern zone of Haryana

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Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is a major cereal crop primarily grown as a food grain in the warmer and drier regions of Africa and Asia. Besides, it also has the potential as an early-maturing summer grain crop in temperate regions (Kumar and Andrews, 1993 and Yoshida and Sumida, 1996). Keeping in view that selection based on its component characters could be more efficient and reliable, knowledge of the association between yield and its component characters and among the component characters themselves would improve the efficiency of selection in plant breeding. Further, the path coefficient analysis measures the direct and indirect influence of one variable upon the other and via other characters on grain yield, respectively permits the separation of genotypic correlation coefficients into components of direct and indirect effects.

Thirty (30) hybrids including two checks (HHB-67 Improved and HHB-226) were sown in a randomized block design (RBD) with three replications in six rows plot of four meter length with spacing of 50 x 20 cm under irrigated conditions at Regional Research Station, CCS HAU, Bawal (Rewari) on July 3, 2011. Four central rows were used for recording observations on various characters. Five competitive and randomly selected plants of each hybrid in each replication were used for recording observations for yield and its component characters i.e. days to 50% flowering, plant height, number of nodes per tiller, inter-node length, effective tillers/plant, ear length, ear girth, days to maturity and grain yield/plant. Protein and fat contents were estimated in laboratory as per standard methods. Phenotypic and genotypic linear correlation coefficients were calculated among characters using the formula suggested by Al-Jiboru *et al.* (1958). The correlation coefficients were further partitioned into direct and indirect effects using the path coefficient analysis according to Dewey and Lu (1959).

Phenotypic and genotypic correlation analysis between different characters (Table 1) contributing to the grain yield revealed that in general genotypic correlation coefficients were higher than the phenotypic correlation coefficients, indicating the vulnerability of environments effects. The results revealed that ear length and ear girth showed significantly positive phenotypic correlations with seed yield per plant. Days to 50% flowering exhibited positive and highly significant phenotypic correlations with plant height (0.57), nodes per tiller (0.47) and days to maturity (0.86), whereas plant height showed positive and significant correlation with nodes per tiller (0.49) and days to maturity (0.41); and ear length with grain yield per plant only.

Ear girth showed positive and significant correlation with 1000-seed weight (0.48) and grain yield per plant (0.37) but negative and significant correlation with effective tillers per plant (-0.42), while effective tillers per plant had significant but negative correlation with nodes per tiller (-0.37) and 1000 seed weight (-0.41). Nodes per tiller showed positive and significant correlation with days to maturity (0.38) only. Protein and fat contents were not significantly associated with grain yield, indicating no adverse effect on grain quality with increasing seed yield.

The correlation coefficients for most of the pairs of characters revealed the presence of strong positive genotypic association between grain yield per plant with ear girth and it is in agreement to previous workers (Kulkarni *et al.* 2000 and Vetriventhan and Kumari, 2007). Significant and positive correlation of grain yield with ear length in the present study is in agreement with the results of Kumari and Nagarajan (2008). Non-significant correlation between protein content and grain yield is in close agreement with those obtained by Deosthale *et al.* (1971) and Kumar *et al.* (1983).

Path analysis based on genotypic correlation coefficients (Table 2) exhibited positive and significant co-relations of plant height, ear length, ear girth and nodes per tiller with seed yield per plant. The results further revealed that days to maturity (2.39) had the

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Table 1. Phenotypic (above Diagonal) and genotypic correlation coefficients (below diagonal) between various characters in pearl millet

Characters	Days to flower	Plant height	Ear length	Ear girth	Effective tillers/ plant	Nodes/ tiller	Inter node length	Test weight	Days to maturity	Protein content	Fat content	Grain yield/ plant
Days to flower		0.57**	0.14	0.27	-0.15	0.47**	0.27	-0.23	0.86**	0.04	0.22	0.16
Plant height	0.70		0.31	0.20	-0.22	0.4**	0.32	0.10	0.41*	0.08	0.10	0.28
Ear length	0.22	0.40		0.10	-0.00	0.01	0.09	0.09	0.07	0.27	0.04	0.43*
Ear girth	0.30	0.20	0.18		-0.42	0.28	-0.17	0.48**	0.28	-0.21	0.05	0.37*
Effective tillers/plant	-0.16	-0.31	-0.01	-0.50		-0.37*	0.21	-0.41*	-0.24	0.24	-0.23	0.10
Nodes/tiller	0.74	0.89	0.14	0.37	-0.50		0.04	0.18	0.38*	-0.08	0.19	0.23
Inter node length	0.57	0.56	0.20	-0.23	0.34	0.54		-0.18	0.19	0.14	-0.10	-0.01
Test weight	-0.24	0.14	0.14	0.50	-0.44	0.30	-0.23		-0.22	-0.14	-0.26	0.18
Days to maturity	0.95	0.57	0.09	0.38	-0.29	0.75	0.40	-0.26		-0.07	0.32	0.15
Protein content	0.05	0.10	0.36	-0.22	0.26	-0.13	0.25	-0.14	-0.08		-0.05	0.03
Fat content	0.23	0.13	0.05	0.06	-0.25	0.29	-0.19	-0.27	0.36	-0.05		0.01
Grain yield/plant	0.29	0.37	0.55	0.49	0.06	0.40	0.06	0.23	0.22	0.040	-0.00	

*, ** Significant at 0.05 and 0.01 probability levels, respectively

Table 2. Direct (diagonal) and indirect effects (off-diagonal) of various characters on grain yield in pearl millet

Characters	Days to flower	Plant height	Ear length	Ear girth	Effective tillers/ plant	Nodes/ tiller	Inter node length	Test weight	Days to maturity	Protein content	Fat content	Genotypic correlation with grain yield/ plant
Days to flower	-2.04	0.83	0.07	0.08	-0.13	-0.67	0.00	-0.15	2.27	-0.00	0.01	0.29
Plant height	-1.42	1.19	0.13	0.06	-0.25	-0. 80	0.00	0.09	1.37	-0.01	0.01	0.37*
Ear length	-0.45	0.48	0.31	0.05	-0.01	-0.12	0.00	0.09	0.22	-0.03	0.00	0.55**
Ear girth	-0.60	0.24	0.058	0.28	-0.41	-0.33	-0.00	0.32	0.90	0.02	0.00	0.49**
Effective tillers/plant	0.32	-0.36	-0.00	-0.14	0.81	0.45	0.00	-0.28	-0.70	-0.02	-0.02	0.06
Nodes/tiller	-1.51	1.06	0.04	0.10	-0.41	-0.90	0.00	0.19	1.80	0.01	0.02	0.40*
Inter node length	-1.17	0.67	0.06	-0.07	0.27	-0.49	0.00	-0.15	0.96	-0.02	-0.01	0.06
Test weight	0.50	0.17	0.04	0.14	-0.35	-0.27	-0.00	0.63	-0.62	0.01	-0.02	0.23
Days to maturity	-1.93	0.68	0.03	0.11	-0.24	-0.68	0.00	-0.17	2.39	0.01	0.02	0.22
Protein content	-0.09	0.11	0.11	-0.06	0.21	0.11	0.00	-0.09	-0.18	-0.10	-0.00	0.04
Fat content	-0.48	0.15	0.02	0.02	-0.20	-0.27	-0.00	-0.17	0.86	0.00	0.06	-0.00

high positive direct effect on grain yield per plant followed by plant height (1.19), effective tillers per plant (0.81), test weight, ear length and ear girth in that order. On the other hand, days to 50% flowering (- 2.04) and nodes per tiller (-0.90) exhibited the high but negative direct effects on grain yield in that order, indicating that early flowering and higher nodes per tiller are not contributing directly towards increasing the seed yield. Positive direct effect of ear girth on grain yield per plant is in close agreement with Ramamoorthi *et al.* (1996) and Berlin and Springer (1998). Ear length had positive direct effect on grain yield per plant and is in agreement with the findings of Harer and Karad (1998).

Days to 50% flowering had high positive indirect effects on grain yield via days to maturity (2.27) and plant height (0.83). Plant height also had high positive indirect effects via days to maturity (1.37) and ear length (0.13). Ear length also contributed positively but indirectly through plant height (0.48) and days to maturity (0.22), whereas ear girth through days to maturity, test weight and plant height; nodes per tiller through days to maturity, plant height, test weight and ear girth; test weight through days to 50% flowering, plant height and ear girth; and days to maturity through plant height and ear girth.

The results further revealed that besides high direct effect, days to maturity had high positive indirect effect on grain yield via most of the traits studied, except effective tillers per plant, test weight and protein content, which was followed by plant height. Path analysis further revealed that positive correlation of nodes per tiller with grain yield was attributed to the high indirect effects via plant height and days to maturity.

Therefore, the present investigations ascertain that seed yield in pearl millet can be enhanced by making selection on the basis of plant height, ear length and ear girth directly besides indirect contribution of days to maturity and plant height via other component characters.

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Production and marketing constraints of vegetable growers in Haryana

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The preponderance of small land holdings, varied agro-climatic conditions and surplus family labour, renders the cultivation of vegetables as most the suitable venture in India. In India and other developing countries to overcome malnutrition, the most serious problem of vulnerable section of the society, there is a great need of cheaper but abundantly available sources of calories, proteins, vitamins and other minerals. Thus, vegetable farming can prove helpful not only in solving the shortage and deficiency of food but also the problem of malnutrition among the common people of our country. In Haryana, the area under vegetable cultivation during 2010-11 was 0.35 m.ha, which shared 6.40% area among leading vegetable producing states, and the maximum area under vegetables was recorded in Gurgaon district. However, compared to the requirement of 300 g per capita/day of vegetables, their availability is about 100 g. Therefore, in order to meet the requirement of packing, processing, seed industry and exports, there is need to produce more vegetables in the state.

Although with improved production technologies, the crop productivity has increased significantly, yet every year fluctuating area and production causing uneven and uncertain supplies of vegetables to the markets, distantly located markets and lack of transport facilities, mainly result into the price fluctuations, which ultimately discourage the farmers to increase area under vegetables. Also at several occasions, the farmers resort to distress sale and even plough back the crop and in disgust throw away the produce on the road side bearing heavy financial losses. Unless the producers realize a higher share of the price paid by the consumers and thereby increase their earnings, there will be very little incentives for them to produce better quality crops and adopt improved practices for higher yield.

Further there is a need to organize training programmes, proper demonstration of improved technologies and introduction of post harvest technologies to encourage the farmers for vegetables production so that they become more economically independent. In order to achieve the stipulated objectives of identifying the constraints in the production and marketing of vegetables, the present study was conducted (2010-11) in the Haryana state by covering three districts i. e. Gurgaon, Kurukshetra and Mahendergarh.

Firstly, based on area under vegetable cultivation and following the Cumulative Cube Root Frequency Method (Singh and Mangat, 1996), the present 21 districts of Haryana were classified into three categories i.e. having the maximum area, intermediate area and the minimum area. From each category, one district and likewise blocks and villages were selected randomly (Table 1). With the help of total cumulative frequency method, the selected 90 vegetable growers were then grouped into three categories namely small (< 3.5 acres), medium (3.5 to 7.0 acres) and large (>7.0 acres).

Keeping in view the objectives of the study, a self designed and pre-tested questionnaire- cum- schedule was used for collection of primary data information from 90 selected respondents related to their socio-economic profile like size of family, education level of farmers, operational land holdings etc. were included in the information. Area under vegetable cultivation, labour used in various farm activities, sources of finance i.e. institutional and non-institutional, decision regarding mode of marketing i.e. wholesale or retail, storage of produce, transportation used in marketing of produce, distance of markets and problems of growers etc. were recorded from the vegetable growers.

It can be seen from the Table 2 that in Haryana high cost of labour was the main problem of the vegetable growers as reported by 80% of the respondents followed by high cost of fertilizer (77.78%), lack of extension services (76.67%), high cost of plant protecting chemicals (75.56%), lack of technical information (73.33%), high attack of insect-pests and diseases (73.33%), adverse weather/climate (73.33%), non-availability of fertilizer at proper time (71.11%), lack of suitable varieties of vegetables for particular agro-climatic region (70.00%), lack of knowledge about the latest packages and practices (poly house) (65.56%), lack of guidance for controlling insect- pests and application of pesticides and fungicides (62.22%), lack of quality seeds (61.11%), scarcity of labour (58.89%), lack of skilled labour (56.67%), high losses at farm level (56.67%) high infestation of weeds (51.11%), low availability of credit (48.89%), high cost of seeds (47.78%), low and

Table 1. Selection of districts, blocks and villages on the basis of area under vegetables and number of selected vegetable growers

Categories (based on area)	Districts in Haryana	Selected districts and block	Selected villages	Selected vegetable growers (in categories)			Total
				Small	Medium	Large	
Maximum	Gurgaon, Karnal, Sonepat and Yamuna Nagar	Gurgaon (Pataudi)	Pahari	5	3	7	15
			Narhera	4	6	5	15
Intermediate	Ambala, Kurukshetra, Panipat, Rohtak and Bhiwani	Kurukshetra (Thanesar)	Shadipur Ladwa	3	7	5	15
			Haryapur	8	3	4	15
Minimum	Panchkula, Fathebad, Faridabad, Kaithal Mahendergarh, Jhajjar,	Mahendergarh (Mahendergarh)	Jasawas	6	6	3	15
	Hisar, Sirsa, Jind, Mewat, Rewari and Palwal		Chamdehra	9	4	2	15
Total	21	3	6	35	29	26	90

Table 2. Production related problems of selected vegetable growers in Haryana during 2010-11

Particulars	Small		Medium		Large		Overall	
	No.	%	No.	%	No.	%	No.	%
High cost of labour	28	80.00	23	79.31	21	80.77	72	80.00
Lack of skilled labour	19	54.29	14	48.28	18	69.23	51	56.67
High cost of seeds	12	34.29	16	55.17	15	57.69	43	47.78
Lack of quality seeds	22	62.86	20	68.97	13	50.00	55	61.11
Shortage of irrigation facilities	16	45.71	11	37.93	9	34.62	36	40.00
Scarcity of labour	21	60.00	18	62.07	14	53.85	53	58.89
High infestation of weeds	18	51.43	16	55.17	12	46.15	46	51.11
Low and imbalanced use of fertilizer	14	40.00	12	41.38	11	42.31	37	41.11
Monsoon failure	17	48.57	14	48.28	6	23.08	37	41.11
Lack of suitable varieties of vegetables for particular agro-climatic region	26	74.29	21	72.41	16	61.54	63	70.00
Lack of technical information	29	82.86	19	65.52	18	69.23	66	73.33
Lack of extension services	32	91.43	18	62.07	19	73.08	69	76.67
Lack of knowledge about latest packages and practices (poly house)	29	82.86	16	55.17	14	53.85	59	65.56
High losses at farm level	16	45.71	19	65.52	16	61.54	51	56.67
High attack of insect-pests and diseases	24	68.57	22	75.86	20	76.92	66	73.33
High cost of plant protection chemicals	22	62.86	25	86.21	21	80.77	68	75.56
High cost of fertilizer	29	82.86	24	82.76	17	65.38	70	77.78
Non-availability of fertilizer at proper time	26	74.29	22	75.86	16	61.54	64	71.11
Adverse weather/climate	28	80.00	24	82.76	14	53.85	66	73.33
Low availability of credit	22	62.86	16	55.17	6	23.08	44	48.89
Lack of guidance for controlling insect-pests and application of pesticides and fungicides	26	74.29	19	65.52	11	42.31	56	62.22

imbalance use of fertilizers (41.11%), monsoon failures (41.11%) and shortage of irrigation facilities (40.00%) Samantaray *et. al.* (2009) on constraints in vegetable production reported similar constraints.

It can be seen from the Table 3 that in the study area too much fluctuations in prices was there which

Table 3. Market related problems of selected vegetable growers in Haryana during 2010-11

Particulars	Small		Medium		Large		Overall	
	No.	%	No.	%	No.	%	No.	%
Lack of suitable packaging material	26	74.29	16	55.17	14	53.85	56	62.22
High cost of storage	29	82.86	19	65.52	17	65.38	65	72.22
Lack of guidance for proper marketing place	24	68.57	17	58.62	15	57.69	56	62.22
Lack of suitable cold storage facilities	22	62.86	15	51.72	13	50.00	50	55.56
High cost of transportation	30	85.71	20	68.97	19	73.08	69	76.67
Lack of market information	28	80.00	22	75.86	21	80.77	71	78.89
Too much fluctuation in prices	32	91.43	26	89.66	23	88.46	81	90.00
Unorganized marketing system	22	62.86	11	37.93	19	73.08	52	57.78
Lack of transportation facilities	14	40.00	16	55.17	10	38.46	40	44.44
Heavy losses in the market	17	48.57	11	37.93	09	34.62	37	41.11
Delay in payment	11	31.43	13	44.83	07	26.92	31	34.44
Malpractices in weighing	19	54.29	15	51.72	12	46.15	46	51.11
Lack of vegetable processing units	27	77.14	20	68.97	20	76.92	67	74.44
Lack of cold-chain facilities (refrigerated transportation and cold storage)	24	68.57	19	65.52	15	57.69	58	64.44
Lack of minimum support prices in vegetables	26	74.29	22	75.86	23	88.46	71	78.89
Lengthy procedure for getting credit from government institutions for marketing purpose	21	60.00	13	44.83	06	23.08	40	44.44

was the biggest and main problem of the vegetable growers in the marketing of their vegetables as reported by 90.00% of the farmers followed by lack of market information (78.89%), lack of minimum support prices in vegetables (78.89%), high cost of transportation (76.67%), lack of vegetable processing units (74.44%), high cost of storage (72.22%), lack of cold-chain facilities (refrigerated transportation and cold storage) (64.44%), lack of suitable packaging material (62.22%), lack of guidance for proper marketing place (62.22%), unorganized marketing system (57.78%), lack of suitable cold storage facilities (55.56%), malpractices in weighing (51.11%), lengthy procedure for getting credit from government institutions for marketing purpose (44.44%),lack of transportation facilities (44.44 per cent) heavy losses in the market (41.11%) and delay in payment (34.44%).Similar constraints were reported by Sharma and Sharma (1993), Parkash (1999) and Pandit *et. al.* (2009) in their studies.

Finally, it was concluded from the study that the high cost of labour was found as the main production related problem of the selected vegetable growers as reported by 80% of the vegetable growers and too much fluctuations in prices as the biggest and main market related problem of the vegetable growers in the study area as reported by 90% of the vegetable growers.

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In text. Singh 1994; Singh 1994a, b; Singh & Malik (1993); (Singh, 1998); (Singh & Malik, 1993); Singh *et al*. (2006); Singh *et al.* (in press); (Singh *et al, in press);* K. P. Singh (unpublished); (K. P. Singh, unpublished); R. K. Mailk (Personal Communications); (R. K Malik, Personal Communications).

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I, Dr. O. P. Nehra, hereby declare that particulars given above are true to the best of my knowledge and belief.

Dated : 31 December, 2012

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(Dr. O. P. Nehra)