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INTERACTIVE EFFECTS OF IRRIGATION AND PHOSPHORUS ON GREEN GRAM *(VIGNA RADIATA* L.*)*

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Abstract

Harvested yields of mung bean are generally very low due to relatively little information on its fertilization and irrigation management. Field experiments were conducted to evaluate the interactive effects of irrigation and phosphorus on green gram (*Vigna radiata* L). Four irrigation levels (I_0 = No irrigation), (I_1 = irrigation at vegetative stage), (I_2 = irrigation at vegetative and flowering stage), (I_3 = irrigation at vegetative, flowering and pod formation stage) and five phosphorus doses ($P_0 = 0$, $P_1 = 20$, $P_2 = 40$, $P_3 = 60$ and $P_4 = 80$ kg ha^{-1}) were arranged in a split plot design with four replications. Irrigation treatments exhibited positive effects on yield and yield components. Less than two and more than two irrigations were not economically beneficial. Phosphorus application @ 40 kg P_2O_5 ha^{-1} affected the crop positively, below and above this level left non-significant effects. Interactive effects of two irrigations and 40 kg P_2O_5 ha^{-1} were most effective. Rest of the combinations remained statistically non-significant to each other. It may be concluded that green gram can be successfully grown under limited water supply when at least two irrigations are given with phosphorus at 40 kg P_2O_5 ha^{-1}. The response of the crop was consistent during both the seasons; however, it was better during the first season than during the second one, which could be attributed to better climatic conditions.

Introduction

Green gram (*V. radiata* L.) is one of the important short season grain legumes in the conventional farming system of tropical and temperate regions. It can be grown on a variety of soil and climatic conditions, as it is tolerant to drought. It is mostly grown under dry land farming system where erratic rains often fetch the crop under moisture stress. Green gram is a principle source of cheap protein (i.e. 22-24%) and essential amino acids. It improves the soil fertility through N_2-fixation and fits well in the existing cropping system of Pakistan. During previous year, it was grown over an area of 257700 ha with production of 138400 tons giving an average yield of 537 kg ha^{-1} (Anon., 2005). Average yield seems to be low as compared to potential of 850 kg ha^{-1}. The yield gap of green gram may be attributed to improper agro-technology being used by the farmers, which can be abridged by adopting advanced production technology comprising the balanced nutrition, high yielding varieties, having characteristics like short stature, earliness and uniform maturity and tolerance to drought and diseases.

The response of a crop to water stress varies with crop species, crop growth stage, soil type, environment and season. Water stress reduces the rate of photosynthesis and uptake of nutrient in green gram (Phogat *et al*., 1984). Water stress also affects crop phenology, leaf area development, flowering, pod setting and finally results in low yield. Most of the economically important leguminous crops have marked moisture sensitive stage, if seed yield is to be taken as the criterion of plant response (Salter & Goode, 1967). Therefore, rate and duration of crop growth need to be synchronized to water availability to get maximum seed yield (Monteith, 1986). Prasad *et al*., (1989) found higher straw and grain yield of green gram with three irrigations as compared to one or no irrigation. Similarly, Sukhivinder *et al*., (1990) found highest dry matter and grain yield of green gram when crop was irrigated thrice. Limited irrigation water availability poses the question as to when and how much to irrigate to achieve the optimum water use efficiency. Thus, it is of paramount importance to determine the growth stage at which the green gram can respond to irrigation more efficiently.

Farmers have a wrong notion that green gram, being legume crop does not need any nutrient and usually grow it on the marginal lands without applying any fertilizer. This seems to be an important reason for low productivity in the country. Contrary to above notion, Hussain (1983) concluded that application of phosphorus to legumes improves seed yield considerably. Similarly, Akhtar *et al*., (1984) found increased number of branches, yield components and yield of green gram compared with treatments given no phosphorus. Increased straw yield, number of pods per plant, number of seeds per pod and thousand grain weight has also been reported by Rathore *et al*., (1992). Adequate amount of phosphorus in soils favours rapid plant growth, early fruiting / maturity and improves the quality of the produce. Sharma *et al*., (1984) studied the combined effects of irrigation and phosphorus and observed the highest availability and uptake of P where highest dose of Phosphorus was applied and wettest regime of irrigation.

Research work about green gram, especially fertilizer management coupled with irrigation has not been given due consideration in the past. Most of the area relating to its production remained unexplored. Thus, the present study was contemplated with the objective to evaluate that up to what extent the interactive effects of irrigation and phosphorus could be effective in improving yield of a commonly grown green gram cultivar.

Materials and Methods

The field experiments were carried out to evaluate the response of green gram to irrigation levels and phosphorus doses at the Agronomic Research Area, of the University of Agriculture, Fasisalabad, (31.25º N, 73.09º E), Pakistan, Physio-chemical properties of soil during both the seasons are given in Table 1.

Table 1. Physio-chemical properties of experimental fields during the two seasons.

Mechanical	**2000**	**2001**
Sand (%)	64	65
Silt (%)	15	15
Clay (%)	22	21
Chemical		
PH	7.60	7.70
Organic matter	0.96	0.99
N (%)	0.04	0.04
Available P ppm	6.65	6.48
Available K ppm	180.00	174.00

The field was under spring maize before planting green gram during both the seasons. Seedbed was prepared by plowing the field three times with tractor-mounted cultivator each followed by planking. Fertilizers NK @ 20:50 kg ha^{-1} were incorporated in the soil with last plowing, while P weighed for each plot as per treatments was also incorporated in the soil with last plowing. Green gram inoculated cv. NM-54 was used as a test cultivar. Crop was sown manually with single row hand drill in 30 cm apart lines using 20 kg seed ha^{-1} in the third week of August 2000 (Season I) and 2001 (Season II). Plant to plant distance of 10 cm was maintained by thinning the seedlings ten days after emergence. The experiments during both the seasons were laid out in a split plot design with irrigation treatments (I_0 = No irrigation (irrigation was given to fallow land 6 days before seedbed preparation), (I_1 = irrigation at vegetative stage), (I_2 = irrigation at vegetative and flowering stage), (I_3 = irrigation at vegetative, flowering and pod formation stage) in main plots and phosphorus treatments ($P_0 = 0$, $P_1 = 20$ kg ha^{-1}, $P_2 = 40$ kg ha^{-1}, $P_3 = 60$ kg ha^{-1} and $P_4 = 80$ kg ha^{-1}) in subplots in net plot size of 3 x 7 m replicated four times. Crop was irrigated as per treatments with canal water measuring approximately 75 mm each irrigation. Crop was monitored throughout crop growth period. Weeds were kept under control with hand weeding as and when required. At maturity central rows leaving two border rows were harvested. The harvested crop was tied in bundles and dried in sun for few days. Yield and yield components of the crop were recorded after sun-drying. Yield components were recorded from ten randomly selected plants while seed yield was recorded from whole plot. The data thus recorded were subjected to standard analysis of variance techniques and means were compared using LSD at 5% probability (Steel & Torrie, 1986). Weather data recorded during both the seasons is given in Table 2.

Results

The year x irrigation and year x phosphorus effects on number of pods per plant were significant. Interaction between irrigation and phosphorus on number of pods per plant was found to be non-significant. During season II, number of pods per plant was 27% less than those recorded during season I (Table 3).

Irrigation levels had a pronounced effect on number of pods per plant compared to control (no irrigation) during both the years of experiments. Crop irrigated twice at vegetative and flowering stage, produced the maximum number of pods per plant during season I, followed by crop irrigated at vegetative + flowering + pod formation stage. Contrary to this, the minimum number of pods per plant was recorded from crop grown without irrigation. The trend similar to season I was observed during season II. Less number of pods per plant was found for treatment where crop was exposed to water stress during flowering and pod formation stage.

Phosphorus fertilizer application also depicted significant effects on number of pods per plant during both the seasons. During season I, the maximum number of pods per plant was recorded for the crop fertilized @ 60 kg ha^{-1} that was statistically at par with the crop fertilized @ 40 kg ha^{-1}. The crop grown without P_2O_5 application produced the minimum number of pods per plant.

The year x irrigation and year x phosphorus interaction depicted significant effects on grains per pod. During season I, the number of grains per pod was 21 % greater than that observed during season II. However, interaction between irrigation and phosphorus on number of grains per pod was found to be non-significant during both the seasons (Table 4).

Table 2. Mean maximum and minimum temperatures (°C) and rainfall (mm) during the two seasons.

Season I	**Mean Maxi. Temp. °C**	**Mean Mini. Temp. °C**	**Rainfall (mm)**
August	40.23	28.12	61.23
September	39.13	39.13	40.0
October	34.62	19.52	10.05
November	27.37	15.23	7.12
Season II			
August	37.63	26.53	39.52
September	34.47	22.13	0.0
October	34.54	22.17	0.0
November	26.84	13.66	0.0

Table 3. Effect of irrigation and phosphorus on number of pods per plant of green gram during the two seasons.

Phosphorus levels (kg ha^{-1})	**Irrigation levels**								**Mean**	
	Io		**I_1**		**I_2**		**I_3**			
	Seasons		**Seasons**		**Seasons**		**Seasons**		**Seasons**	
	I	**II**	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**
P_o (00)	15.0	13.0	18.8	14.2	20.0	16.0	18.8	14.1	18.1	14.3
P_1 (20)	17.0	14.3	19.1	14.1	24.4	16.2	22.9	14.0	20.9	14.7
P_2 (40)	19.8	15.1	22.6	17.2	26.3	19.0	25.0	18.0	23.4	17.3
P_3 (60)	20.3	15.0	24.4	16.1	25.4	19.0	24.5	17.3	23.6	16.9
P_4 (80)	20.8	15.3	22.0	16.0	26.0	18.1	23.8	16.8	23.1	16.6
Mean	18.6	14.5	21.4	15.5	24.4	17.7	22.9	16.0		

LSD (0.5%) Irrigation levels: Season I: 1.26, Season II: 0.98
Phosphorus levels: Season I: 1.08, Season II: 0.77
Interaction: NS

Table 4. Effect of irrigation and phosphorus on number of grains per pod of green gram during the two seasons.

Phosphorus levels (kg ha^{-1})	**Irrigation levels**								**Mean**	
	Io		**I_1**		**I_2**		**I_3**			
	Seasons		**Seasons**		**Seasons**		**Seasons**			
	I	**II**	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**
P_o (00)	10.8	7.6	11.0	8.0	11.5	8.4	11.3	8.4	10.6	8.1
P_1 (20)	11.4	8.0	11.8	8.8	12.0	8.8	11.6	9.2	11.4	8.7
P_2 (40)	10.6	8.1	11.5	8.2	11.7	10.8	11.5	9.4	11.6	9.4
P_3 (60)	10.5	8.8	11.0	8.4	11.8	10.0	11.8	9.4	11.3	9.2
P_4 (80)	10.0	9.0	11.0	8.4	10.3	10.0	11.2	9.8	11.1	9.3
Mean	10.7	8.3	11.3	8.6	11.5	9.6	11.5	9.2		

LSD Irrigation levels: Season I: 0.55, Season II: 0.70
Phosphorus levels: Season I: 0.58, Season II: 0.70
Interaction: NS

Irrigation caused a significant increase in number of grains per pod compared to control. During season I, irrigation either at vegetative + flowering or vegetative + flowering + pod formation stage remained equally better than control. However, during season II, crop irrigated at vegetative + flowering or vegetative + flowering + pod formation stage produced higher number of grains per pod compared to the crop irrigated only at vegetative or not irrigated. Thus amount of water applied had pronounced effect on number of grains per pod.

Various phosphorus levels also affected the number of grains per pod significantly. During season I, the maximum grains per pod were attained by P_2 (40 kg ha^{-1}) that was at par to P_1 and P_3. The trend similar to season I was observed during season II.

The year x irrigation and year x phosphorus effect on test weight was significant. During season I, grains were heavier by 12.92 % than those during season II (Table 5). Interactive effect of irrigation and phosphorus was found to be non-significant during season I, but significant during season II. The crop irrigated twice at vegetative + flowering stage fertilized @ 40, 60 or 80 P_2O_5 kg ha^{-1} produced heavier grains compared to other interactions and were statistically non-significant with each other. On the contrary, crop grown without irrigation and fertilized @ 0 and 20 kg ha^{-1} produced the minimum thousand grain weight (Table 5).

Different irrigation levels affected the thousand grain weight significantly. During season I, crop grown with two irrigations at vegetative + flowering stage (I_2) produced the maximum thousand grain weight, that was however statistically at par with I_1. Crop grown with no irrigation (Io) or three irrigation (I_3) (vegetative +flowering + pod formation stage) produced the minimum thousand grain weight and were statistically at par with each other. However, during season II, control crop produced substantially lighter grains than other treatments.

During season I, phosphorus application exhibited a non-significant effect on thousand grain weight, but significant during season II. The crop fertilized @ 40 or 60 kg ha^{-1} produced significantly heavier grains than other treatments.

The year x irrigation and year x phosphorus effects on grain yield was significant. During season I, grain yield was 32.55 % higher than that recorded during season II. However, the interactive effects of irrigation and phosphorus on grain yield were found to be non-significant during both the seasons (Table 6).

Different irrigation levels exhibited non-significant effects on grain yield during season I, but were significant during season II. During season II, the highest grain yield (789.4 kg ha^{-1}) was recorded for the treatment where crop was irrigated at vegetative +flowering stage, followed by treatment where crop was irrigated at vegetative + flowering + pod formation stage. On the contrary, the lowest grain yield (534.6 kg ha^{-1}) was obtained for control

Various P_2O_5 levels affected the grain yield significantly during both the seasons. During season I, the maximum grain yield (1104 kg ha^{-1}) was recorded for the crop fertilized @ 40 kg ha^{-1} P_2O_5 that was, however, statistically at par with the crop fertilized @ 60 kg ha^{-1} P_2O_5. On the contrary, the crop grown without P_2O_5 fertilization exhibited the lowest grain yield (904.84 kg ha^{-1}). During season II, grain yield was lower for respective treatment compared with that during season I. However, the trend was similar for both the years.

Table 5. Effect of irrigation and phosphorus on 1000-grain weight (g) of green gram during the two seasons

Phosphorus levels (kg ha^{-1})	Irrigation levels								Mean	
	Io		I_1		I_2		I_3			
	Seasons		Seasons		Seasons		Seasons		Seasons	
	I	II	I	II	I	II	I	II	I	II
P_o (00)	47.8	40.0	50.0	41.5	50.8	46.2	50.9	43.9	49.8	43.3
P_1 (20)	50.0	39.0	52.0	43.1	53.3	47.8	52.0	46.0	51.9	44.6
P_2 (40)	52.2	41.2	53.8	45.8	54.3	50.0	51.0	46.5	52.8	45.9
P_3 (60)	52.8	41.5	52.5	46.0	52.7	51.5	50.0	46.2	52.0	46.3
P_4 (80)	52.0	41.5	53.8	46.0	52.0	50.6	50.0	42.0	52.2	45.0
Mean	50.9	40.5	52.4	45.4	52.8	49.2	50.8	44.9		

LSD Irrigation levels: Season I: 1.43, Season II: 1.04
Phosphorus levels: Season I: NS, Season II: 1.07
Interaction: Season I: NS, Season II : 2.14

Table 6. Effect of irrigation and phosphorus on grain yield (kg ha^{-1}) of green gram during the two seasons.

Phosphorus levels (kg ha^{-1})	Irrigation levels								Mean	
	Io		I_1		I_2		I_3			
	Seasons		Seasons		Seasons		Seasons		Seasons	
	I	II	I	II	I	II	I	II	I	II
P_o (00)	43.3	484.9	911.1	575.8	962.3	657.6	902.8	666.7	904.9	596.2
P_1 (20)	02.8	469.9	1021.4	636.4	1094.5	781.8	962.3	703.8	995.3	647.9
P_2 (40)	82.2	515.2	1184.6	757.6	1200.8	886.7	1051.6	796.2	1104.8	738.9
P_3 (60)	82.2	596.9	1087.2	696.9	1083.0	818.1	982.2	761.3	1033.7	718.3
P_4 (80)	952.4	606.0	1096.4	686.7	1051.5	803.0	912.7	712.7	1003.3	702.1
Mean	932.6	534.6	1060.1	670.7	1078.4	789.4	962.3	728.1		

LSD Irrigation levels: Season I: NS, Season II: 39.18
Phosphorus levels: Season I: 82.35, Season II: 29.47
Interaction: NS

Discussion

Mung bean or green gram is a short-season summer-growing grain legume grown predominantly under dry land conditions throughout the tropics and subtropics. Due to the erratic nature of summer rains and variation in stored soil water at sowing, the crop is exposed to varying timing and severity of water deficit, which results in variability in grain yield. The vegetative growth of mung bean mostly ceases at the onset of the reproductive phase; the crop is able to produce second flushes of flowers if conditions are favorable (Ludlow & Muchow 1990). In the present study, the reduction in number of pods per plant might have been due to abscission of flowers and pods under moisture stress, the second year received less rains as compared to the first year so less pods were observed. At flowering stage green gram (*V. radiata*) is considered to be more sensitive to water stress than during vegetative stage, because at the former stage even short duration of diurnal fluctuation in plant water content could drastically influence the development and function of reproductive organ. Muchow (1985) reported that green gram is very sensitive to water stress during flowering and grain formation than vegetative stage. Similarly, Pandey *et al*., (1984) also found that irrigation increased the number of grains per pod. The reduction in seed weight in case of less irrigation water supply might be due to the decreased photosynthetic activity. Overall less yield recorded in treatments where less irrigation water was supplied may be related to contribution of yield attributes. Water stress reduced plant growth and yield regardless of whether the stress was imposed when the plants were in the vegetative or reproductive stage of development (Thomas *et al*., 2004). However, water stress during the reproductive stage affected grain yield more severely. In the present study, irrigation applied at vegetative and flowering stage might have resulted in adequate and timely availability of nutrients, which boosted the crop development resulting in higher yields. Haq *et al*., (1996) found a significant increase of yield where crop was watered properly as compared where crop faced water stress.

Phosphorus plays a fundamental role in many of the plants physiological processes such as the utilization of sugar and starch, photosynthesis and the transfer of energy. Furthermore, phosphorus increases the strength of cereal straw, stimulates root development and promotes flower formation and fruit production. It hastens maturity of crops grown on soils low in phosphorus. Adequate P supply may improve quality of harvest as well (Anon., 1988). Positive effects of phosphorus applied @ 40 kg ha^{-1} observed in the present study are in agreement with the findings of Yadav *et al*., (1992) who recorded an increase in seed yield of peas from 1.47 to 1.81 tons ha^{-1} when the crop was irrigated at flowering + pod formation compared with crop irrigated at flowering and fertilized @ 25 kg ha^{-1} P. Increase in seed yield due to phosphorus application was attributed to profound branching, better fruiting, increased number of seeds per pod and heavier seeds. However, higher doses failed to improve the growth and yield while lower than 40 kg P_2O_5 ha^{-1} seems to be less than the requirement. During season I, better climatic conditions during crop growth (Table 2) period might have resulted in more number of branches, pods, grains and thousand grains weight those ultimately increased the overall yield than that during season II.

Though interaction between irrigation and phosphorus on grain yield remained non-significant, the combination of two irrigations fertilized @ 40 kg ha^{-1} was found to be the best as indicated by the highest grain yield. It also provided the clue that fertilizer without adequate moisture available to plants would not be much beneficial. The irrigation requirements of green gram are low, application of water more than the required would be the mere wastage of resources. It would promote vegetative growth, delay flowering and thus late formed pods would not bear required grains (Malik 1997). It may be concluded that green gram can successfully be grown with two irrigations coupled with phosphorus application of 40 kg ha^{-1}.

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