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Influence of Phosphorus Application and Sowing Time on Performance of Wheat in Calcareous Soils

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ABSTRACT

An experiment on the agronomic response of wheat (*Triticum aestivum* L.) sown at different dates to phosphorus application in calcareous soil for increase in yield was conducted under arid climates during 2005-06 and 2006-07. The crop was sown in calcareous silty loam soil on 25th day of October, November and December, and phosphorus levels were 60, 90 and 120 kg ha^{-1}. The data on various agronomic characteristics were recorded following standard procedures. There was a consistent decrease in grain yield with delay in sowing from October 25 to December 25. There was a progressive increase in grain yield of wheat with each increment from 60 to 120 kg P ha^{-1} from the crop fertilized being maximum from 120 kg P ha^{-1}. The crop duration of the wheat sown on December 25 and fertilized at 120 kg P ha^{-1} was 42 days shorter as compared to that sown on October 25 and fertilized with 60 kg P ha^{-1}. Various crop traits such as number of fertile tillers, 1000-grain weight and number of grains per spike were significantly influenced by sowing dates and phosphorus application. Similarly, fertilization with at 120 kg P ha^{-1} maximally improved all these traits in both the years. As a result of interactive effect of early sowing time (October 25) and the highest dose of phosphorus, (120 kg ha^{-1}) gave maximum yield.

Key Words: Wheat; Sowing times; Phosphorus levels; Calcareous soils

INTRODUCTION

Land used for crop production in Pakistan is approximately 22 million hectares that is mostly calcareous in nature (Ahmad, 1992). About 90% soils are deficient in nitrogen and phosphorus and 40% in potassium (Ahmad & Rashid, 2004). The deficiency of phosphorus (P) is further aggravated by 60% lesser use of recommended P. The N: P_2O_5: K_2O ratio during 2000-03 has averaged 1: 0.28: 0.01 (Ahmad & Rashid, 2004) that is not matching with the recommended ratio of 1:1: 0.50 (Shah, 1994). The declining trend in soil phosphorus has been computed to be at 0.016 ppm per year in Punjab soils (Malik *et al*., 1992).

Superphosphate applied to the alkaline calcareous soils gets converted into insoluble calcium phosphate (49-59%), iron and aluminum phosphate (14-19%), while water soluble fraction ranges between 5-9% only (Ahmad *et al*., 1992). The plant tissues recover only 11-19% of the applied phosphorus (Sharif, 1985). The average phosphorus fixation of the added phosphorus in clay, clay loam, loam, sandy loam and loamy sand soils is 71, 62, 56, 29 and 29%, respectively after one month of incubation (Chaudhry & Qureshi, 1982).

Sowing time is an essential production factor for increasing the yield of wheat. Adverse environmental conditions sometimes delay wheat sowing and cause a considerable reduction in grain yield. Wheat is sown in the province of Punjab, Pakistan from early November to end of December or even first weak of January over a period of 60 to 70 days. Late planting of wheat is a major agronomic problem in most rice-wheat and cotton-wheat areas of South Asia (Fujisaka *et al*., 1994) in general, and Pakistan in particular (Khan, 2000). Delay in planting after November 25 reduces wheat yield and reduction is almost linear. There were 8, 16, 32 and 50% reduction, respectively for each fortnight after November 10 (Khan, 2003). The yield reduction was due to a shorter growing period available to the late planted wheat. Being determinate plant there was a non-significant effect of planting dates on maturity, because sudden rise in temperature during the month of April turned the crop towards maturity irrespective of planting dates. All phases of plant growth, tillering, flowering, grain filling are adversely affected by the shortened growing period.

Previous studies have shown that higher dose of P can compensate for the loss in grain yield of wheat due to late sowing, since it helps in rapid development of root and seedling (Blue *et al.,* 1990). Moreover, it encourages tillering, promotes early and uniform heading, increases water use efficiency and hastens crop maturity (Gupta, 2003). Early sown wheat with low application of P proved better than late sown with high P application. This led to conclude that early sowing of wheat for optimum yields

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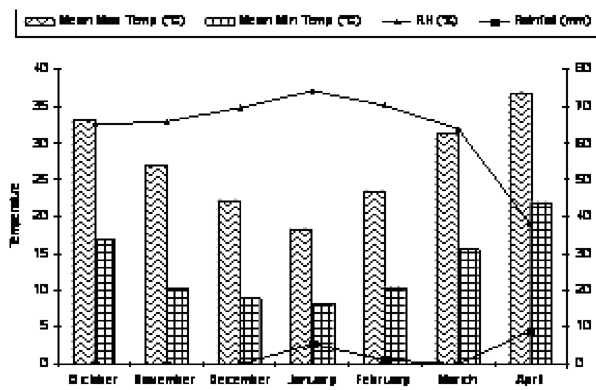
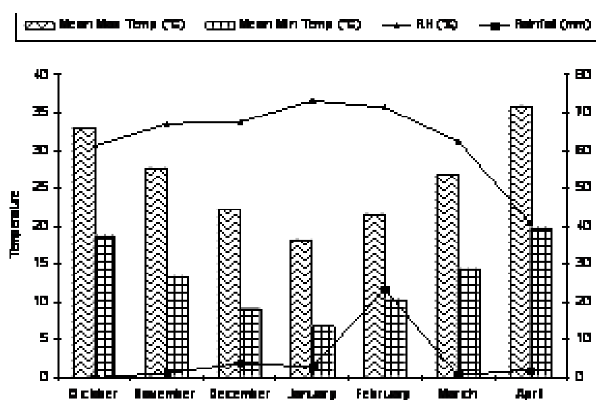
with lower inputs of P fertilizer depending upon the low phosphorus-use efficiency (PUE) and quicker depletion of soil P (Batten *et al*., 1999). Dahatonde and Tiwane (1992) stated that wheat sown on 15th or 30th November or 15th or 30th December produced mean grain yield of 3.62, 3.11, 2.52 and 1.74 t ha^{-1}, respectively. Grain yield was less affected by fertilizer N (60, 80, 100, or 120 kg ha^{-1}) or P (30, 40 & 50 kg ha^{-1}) application. Gomez-Macpherson and Richards (1998) reported that variation in grain yield between the earliest sowing and normal sowings while 1.3% decrease in grain yield was recorded in late sowing. Iglesias (1992) reported that wheat cultivar ‘Anahuae’ sown on 14 different dates between 9 Oct and 1st March at a seeding rate of 90 kg ha^{-1} and given 110 kg N, 80 kg P and 60 kg K ha^{-1}, produced the highest grain yields 7.6 t ha^{-1} and 7.1 t ha $^{-1}$ followed by sowing in late November and late December. This study evaluated the agronomic response of wheat (*Triticum aestivum* L.) sown at different dates to phosphorus application in calcareous soil for increasing yield.

Fig. 1. Meteorological data for growing period of crops (October- April) during the year 2005-2006 (A) and 2006-2007 (B) showing rain fall and temperature fluctuation and relative humidity

(A). Year 2005-2006



(B). Year2006-2007



MATERIALS AND METHODS

The study was conducted at the Experimental Farm, University College of Agriculture, Bahauddin Zakariya University, Multan, (latitude= 30.15° N 544, longitude= 71.30° E 885, altitude = 126.6 m) during 2005-2006 and 2006-2007. Textural class of soil was silty loam, with the following physico-chemical analysis: sand 28-26%, silt 54-56% and Clay18-17% and chemical analysis indicated saturation 39-37%, pH of 8.08-8.10, EC (dS m^{-1}) 3.00-3.09, organic matter 0.69-0.76% and N 0.04-0.05%, P_2O_5 5.25 to 5.5 mg L^{-1}, K_2O 250-300 mg L^{-1}, Zn 0.38-0.36 and $CaCO_3$ 9.0-9.1% in the two growing seasons.

The experiment comprised three sowing dates: 25th day of October, November and December and three phosphorus (P as P_2O_5) levels (60, 90 and 120 kg ha^{-1}). The experiment was laid out in a randomized complete block design with split plot arrangement keeping sowing dates in main plots and P levels in sub-plots measuring 1.6×6 m each. Wheat cultivar Inqulab-91 was sown on a well prepared seed bed on respective sowing dates during the two cropping seasons with the help of a single row hand drill in 20 cm spaced rows using seed rate of 125 kg ha^{-1}. A basal dose of nitrogen (N) and potash (K) each at the rate of 57 and 65 kg ha^{-1} was applied in the form of urea and potassium sulphate, respectively. Phosphorus for all treatments was applied in the form of single superphosphate. The whole of P and K along with half dose of N (57 kg ha^{-1}) was applied at sowing, while the remaining half N dose was top-dressed with first irrigation. First irrigation was applied three weeks after sowing the crop, while subsequent irrigations were applied as and when needed. In all five irrigations each of 7.5 cm depth excluding pre-soaking irrigation were applied from sowing to harvesting during both the years. Herbicides Logran ext. 64 WG (Terbutryn+ triasulfuron) @ 250 g ha^{-1} and Topik 15 WP (Clodinafop propargyl+ cloquinitocet mexyl) @ 250g ha^{-1} were used to control broad and narrow leaved weeds each after 1st and 2nd irrigation, respectively at optimum soil moisture conditions. All other agronomic practices were kept normal and uniform for all the treatments. Data on biological yield (total biomass of plant above ground), grain yield, plant height, spike length, number of fertile tillers, days taken to maturity was taken at harvest, whereas 1000-grain weight, number of grains per spike, harvest index after the crop harvest and leaf area index at 90 days after sowing (DAS) were recorded during the course of studies.

The data were analyzed statistically using computer statistical program MSTAT-C (Freed & Scott, 1986). Analysis of variance was employed to test the overall significance of the data, while the least significance difference (LSD) test at P=0.05 was used to compare the differences among treatment means. Meteorological data for the entire growing period of the experimental crop during each year (Fig. 1A & B) were solicited from Agro-meteorological section of Central Cotton Research Institute (CCRI), Multan.

RESULTS

Data revealed that the year as well as the interactive effect of sowing dates and phosphorus on fertile tillers was non-significant. Different P levels did not influence the number of fertile tillers. By contrast, there was a significant variation among various planting dates. Number of fertile tillers decreased linearly (284-265) with successive delay in sowing from October 25 to December 25.

The effect of sowing dates and phosphorus levels on plant height were significant and their interaction was non-significant during both the years. The early sown crop (October 25) produced taller plants (94.56 cm) than the mid sown crop, which was superior to the latest sown crop (Table II). A progressive increase in plant height occurred with each increase in P level from 60 to 120 kg ha^{-1}, which varied from 89.89 to 93.34 cm (P = 0.05). The crop sown on October 25 and fertilized with 90 or 120 kg P ha^{-1} produced taller plant than rest of the treatments. The minimum plant height (86.93 cm) was recorded from crop sown on December 25 and fertilized with 60 kg ha^{-1} P. The results further indicated that higher P doses interacted favorably with early sowing for plant height of wheat.

The number of grains per spike was affected significantly both by phosphorus application and sowing dates but their interaction was non-significant. Although the crop sown on October 25 produced significantly greater number of grains per spike (45.08) than that sown on December 25 (39.00), it exhibited similar number of grains per spike (44.08) as recorded from November 25 sown crop (Table II). There was a significant variation among different P levels. Although the crop fertilized with 120 kg P ha^{-1} produced greater number of grains per spike (43.75) than that fertilized with 60 kg ha^{-1} P, but was at par with the crop fertilized with 90 kg ha^{-1} P fertilization.

The data on 1000-grain weight evinced significant influence of sowing dates and P application in wheat. Among the sowing dates, the crop sown on October 25 produced significantly heaviest grains (39.99 g) than that sown on either of the subsequent dates, which differed significantly from each other (Table II). As regards P levels, there was a progressive increase in 1000-grain weight with gradual increase in P dose from 60 to 120 kg p ha^{-1}.

Both, sowing dates and P levels influenced wheat grain yield but their interactive effect was non-significant (P = 0.05) during both the years. There was a consecutive decrease (26%) in grain yield during 2005-2006 and 2006-2007, respectively with delay in sowing after October 25 to December 25. As regards P levels, the crop fertilized with 120 kg ha^{-1} P produced significantly higher grain yield (3.76 t ha^{-1}) than the that fertilized with 90 kg ha^{-1} P_2O_5 (3.64 t ha^{-1}) followed by 60 kg ha^{-1} P (3.52 t ha^{-1}).

Sowing dates and phosphorus levels significantly influenced biological yield, while the interactive effect of both of these factors was non-significant in both the years. Delay in sowing from October 25 to December 25 decreased biological yield of wheat over the years. Biological yield of wheat was reduced 25-26%, when sowing was delayed as compared with early sown crop (Table II). Increased levels of P enhanced biological yield of wheat during both the years (Table I). During 2005-2006 crop fertilized at 60 and 90 ka ha^{-1} P produced similar biological yield (8.90-9.09 t ha^{-1}) that was significantly (P= 0.05) lower than that obtained with the application of 120 kg ha^{-1} P_2O_5. During 2006-2007, application of P at last two levels gave yield that was higher than the lowest level.

Sowing dates and P levels significantly influenced harvest index (HI). On an average delay in sowing reduced the HI by 1 to 2%, respectively the difference between later sowing dates being. On the other hand, increasing P levels progressively improved HI by 2%. A highest HI (40.55%) was noted for the crop sown on October 25 and applied with 120 kg P compared to the minimum (38.81%) for the crop planted on December 25 and fertilized with 60 kg P ha^{-1} (Table II)

At 90 DAS, planting dates, P levels and their combinations significantly influenced leaf area index (LAI) during both the years. A maximum LAI (5.34) was recorded for the crop sown on Oct. 25 and fertilized with 120 kg P ha^{-1} followed by the crop fertilized with 90 kg P ha^{-1} and sown on October 25 producing LAI of 5.04 (Table III). By contrast, a minimum LAI (3.37) was recorded from December 25 sown crop and fertilized with 60 kg P ha^{-1}. Sowing date can have a profound influence on the LAI.

Both the interactive and main effects of sowing dates and P application on days taken to maturity were significant in both the years. The earlier sown crop and fertilized with 60 kg P ha^{-1} took significantly more longer time (158 days) to mature than rest of the treatments. Moreover, the late sown wheat and receiving higher rates of P fertilizer took lesser number of days to mature as compared with late sown crop and with lower rate of P fertilizer (Table III).

DISCUSSION

The final grain yield of wheat was proportional to the number of fertile tiller. Linear reduction in fertile tillers due to delay in sowing was ascribed to variable temperature regime and environmental composition at different sowing dates (Table I). However, it is not clear whether this effect was the consequence of less prolific tillering or of higher tiller mortality (Hay & Walker, 1989). Shivani *et al.* (2003), Ejaz *et al.* (2002) and Khan (2003 & 2004) reported that timely seeded wheat (November 21) produced more tillers.

In the present study, application of different levels of phosphorus showed a non-significant difference on fertile tillers (Table I & II), which corroborated the findings of Hussain *et al*. (2004). Early sowing produced taller plants then late, showing the same trend as mention by Khan (2000) who stated that a short stature of plants in late sown wheat might be attributed to the low temperature at earlier stages of plant growth and development. Another reason for

Table I. Influence of Phosphorus application on the performance of wheat in calcareous soils

Parameters	Phosphorus Levels									LSD 0.05
	P_1 (60 Kgha^{1})			P_2 (90 Kgha^{-1})			P_3 (120 Kgha^{-1})			
	2005-06	2006-07	Mean	2005-06	2006-07	Mean	2005-06	2006-07	Mean	
No. of fertile tillers	272	274	273	274	277	276	276	278	277	P_1=ns P_2=ns
Plant height(cm)	90.44c	89.34c	89.89c	92.53b	91.63b	92.08b	93.81a	92.87a	93.34a	P_1=0.633 P_2=0.563
No. of grains spike^{-1}	41.50	41.67	41.58b	42.58	43.08	42.83ab	43.50	44.00	43.75a	P_1=ns P_2=ns
1000-grain weight (g)	35.92c	36.05c	35.99c	36.88b	37.01b	36.95b	38.05a	38.15a	38.10a	P_1=0.210 P_2=0.168
Grain yield (Kgha^{-1})	3.47c	3.57c	3.52c	3.58b	3.69b	3.64b	3.71a	3.80a	3.76a	P_1=0.081 P_2=0.112
Biological yield (Kgha^{-1})	8.90b	9.21c	9.05c	9.09b	9.44ab	9.26b	9.34a	9.51a	9.43a	P_1=0.203 P_2=0.271
Harvest index (%)	39.01c	38.82c	38.92c	39.41b	39.11b	39.26b	39.82a	39.93a	39.87a	P_1=0.346 P_2=0.222
Leaf area index	4.10c	4.19c	4.14c	4.30b	4.38b	4.34b	4.47a	4.54a	4.51a	P_1=0.047 P_2=0.047
Days taken to maturity	139a	138a	139a	136b	134b	135b	132c	129c	131c	P_1=2.077 P_2=1.998

Any two means not sharing a letter differ significantly at (P=0.05)
Note: P_1 and P_2 are denoted for LSD value for year 2005-06 and 2006-07 respectively.

Table II. Influence of sowing dates on the performance of wheat in calcareous soils

Parameters	Sowing Dates									LSD 0.05
	October 25 (S_1)			November25 (S_2)			December 25 (S_3)			
	2005-06	2006-07	Mean	2005-06	2006-07	Mean	2005-06	2006-07	Mean	
No. of fertile tillers	283a	286a	284a	275a	276ab	276b	265b	266b	265c	S_1=10.81 S_2=10.81
Plant height(cm)	95.14a	93.99a	94.56a	92.03b	91.53b	91.78b	89.60c	88.33c	88.96c	S_1=0.824 S_2=0.466
No. of grains spike^{-1}	44.92a	45.25a	45.08a	43.75a	44.42a	44.08a	38.92b	39.08b	39.00b	S_1=4.634 S_2=3.034
1000-grain weight (g)	39.90a	40.40a	39.99a	36.93b	37.04b	36.98b	34.02c	34.13c	34.08c	S_1=0.398 S_2=0.427
Grain yield (Kgha^{-1})	4.05a	4.16a	4.10a	3.81b	3.84b	3.78b	3.00c	3.07c	3.03c	S_1=0.122 S_2=0.122
Biological yield (Kgha^{-1})	10.28a	10.45a	10.37a	9.42b	9.86b	9.65b	7.62c	7.84c	7.73c	S_1=0.301 S_2=0.272
Harvest index (%)	39.41	39.76a	39.58a	39.49	38.97b	39.23b	39.34	39.14b	39.24b	S_1=ns S_2=0.274
Leaf area index	5.00a	5.08a	5.04a	4.42b	4.50b	4.46b	3.45c	3.53c	3.49c	S_1=0.063 S_2=0.054
Days taken to maturity	155a	152a	153a	135b	132b	133b	118c	118c	118c	S_1=1.067 S_2=1.698

Any two means not sharing a letter differ significantly at (P=0.05); **Note:** S_1 and S_2 are denoted for LSD value for year 2005-06 and 2006-07 respectively.

Table III. Influence of phosphorus levels and sowing dates on the performance of wheat in calcareous soils

Parameters	Phosphorus levels and Sowing Dates									LSD 0.05
	P_1S_1	P_1S_2	P_1S_3	P_2S_1	P_2S_2	P_2S_3	P_3S_1	P_3S_2	P_3S_3	
No. of fertile tillers	281	273	262	286	274	264	286	277	267	ns
Plant height(cm)	92.65	90.09	86.93	94.96	92.29	88.99	96.08	92.96	90,98	ns
No. of grains spike^{-1}	43.88	43.25	37.63	45.25	44.13	3913	46.16	44.88	40.25	ns
1000-grain weight (g)	39.00	35.99	32.99	39.89	36.96	33.91	40.99	38.00	35.33	ns
Grain yield (Kgha^{-1})	3.96	3.70	2.90	4.09	3.78	3.04	4.26	3.85	3.16	ns
Biological yield (Kgha^{-1})	10.16	9.52	7.47	10.42	9.63	7.74	10.52	9.87	7.98	ns
Harvest index (%)	38.94de33 38.94de	39.00de	38.81e	39.26cd	39.26cd	39.26cd	40.55a	39.43bc	39.65b	0.344
Leaf area index	4.73c	4.32f	3.37i	5.04b	4.46e	3.52h	5.34a	4.60d	3.58g	0.055
Days taken to maturity	158a	138d	120g	153b	134e	117h	148c	128f	116h	1.84

Any two means not sharing a letter differ significantly at (P=0.05)

taller plants in early sown crop was availability with longer time to grow (difference of 30 days in first two dates of sowing and 60 days during first and last sowing). This implicated that more solar radiations were available to the early sown crop that resulted in taller plants (Ejaz *et al*., 2002; Khan, 2004). Promotion effect of high P level on plant height was probably due to better development of root system and nutrient absorption (Tandon, 1992; Mandal *et al*., 1992; Tanner, 1992; Hussain *et al*., 2004).

The number of grains per spike was non-significantly affected by early and mid sowing where as in case of late sowing number of grains were reduced up to 15% (Table I & II). The acceleration in the rate of crop development associated with delay in sowing reduces the duration of phase of spikelet initiation. Jessop and Ivins (1970) demonstrated a pronounced tendency toward larger ear at the latest of their three sowings of spring cereals. Likewise, Ali *et al*. (1982) reported that number of grains per spike was related to the length of growing season. Variation in sowing date is commonly found to have a negligible influence upon the number of grains per ear (Kirby, 1969; Harris, 1984). Hence, the grains per spike might be controlled genetically. Early to mid sowing had no effect on grain number but crop sown late in December reduced the grain number in present study.

Wheat crop responded better to higher dose of P in this study that might have contributed to better root development and nutrient absorption from the soil. Profound effect of higher doses of P on grains per spike was also reported by Hussain *et al*. (2004). It was found that higher dose of P and early sown crop produced 6% more grain weight as compared to lower level of P, and delayed sowing. Normally the conditions during grain filling tend to be similar for crop sown on different dates. However, due to other aspects of the acceleration of development (in particular lower crop dry weight at anthesis), there may also be a tendency for late sown crop to give lighter grain yield (Hay & Walker, 1989; Andrew *et al*., 1990). It is concluded that P application in appropriate amount promoted grain development in wheat (Brennan, 1992).

Grain yield varied significantly during both the years of experimentation. On an average grain yield was about 3% higher during 2006-2007 than the previous year (Table I & II). The yield difference between years might be attributed to variable temperature and rainfall regimes during both the years (Fig. 1A & B) leading to greater leaf area duration and average crop growth rate during 2nd year. The decrease in grain yield across the sowing dates might be attributed to reduced crop growth in terms of lower total leaf area indices, leaf area duration, crop growth rate and ultimately lower total dry matter production and poor harvest indices under delayed sowing. Yield reduction in wheat as a consequence of delay in sowing has been reported by several authors (Mian *et al*., 1984; Fida *et al*., 1998; Edwin *et al*., 2001; Ejaz *et al*., 2002; Khan, 2003 & 2004). Fertile spikes per unit area, grains per spike and 1000 grain weight mainly contribute in the economic yield of wheat crop. There was a promoting effect of P fertilizer on the aforementioned yield components (Zhu *et al*., 2001; Hussain *et al*., 2004).

Biological yield of wheat was significantly higher (P = 0.05) during the second year than the first year (Table III), probably because of relatively more favorable agro-environmental conditions during this year (Fig. 1A & B). The reduction in biological yield as a result of delay in sowing might be attributed to the variable length of crop growth period and environmental conditions. Temperature declined gradually after first sowing date and this trend continued throughout winter. Low temperature at early vegetative period in late sown crop suppressed vegetative growth leading to overall reduction in biological yield in late sown crop. On the other hand early sown crop experienced comparatively high temperature regimes resulting in better vegetative growth. Tillers per unit area, plant height, grains per spike and grain weight all contribute in to biological yield (Table I, II & III). The promotive effect of early sowing on biological yield has been reported (Iftikhar *et al*., 1992; Edwin *et al*., 2001; Ejaz *et al*., 2002). Increase in dry matter yield with the application of phosphatic fertilizer has also been reported by Hameed *et al*. (2002) and Hussain *et al*. (2004).

On an average crop matured two days earlier than the first year showing a significant difference (P = 0.05) for years. This occurred probably, because of relatively higher mean temperature and low relative humidity prevailing during the maturity period of crop during 2006-2007 (Fig. 1A & B). When planting was delayed, the development of plant organs and transfer from source to sink were remarkably affected, as reflected from overall shortening of plant height, reduction in number of internodes, days to heading days to maturity and grain filling period and ultimately in reduction of yield and yield components (Mahboob *et al*., 2005). These results are in consonance with those of Tandan (1992) who reported the importance of P and sowing time for the maturity of wheat crop.

Delay in sowing from October to December may reduce harvest index, which was improved by increasing P levels (Table III). Similar results were reported by Blue *et al.* (1990) who reported positive effects of early sowing and P application on harvest index of wheat crop. Extent of development of leaf area indices varied significantly (P = 0.05) during both the years in this study, giving relatively higher LAI during the 2nd year than the previous year. Early sown crop during both the years had higher LAI and the differences became wider with the advancement in developmental stage of the crop. In all treatments, LAI declined sharply towards maturity probably owing to senescence. Shivani *et al.* (2003) reported that timely seeded wheat (November 21) recorded maximum LAI.

Our studies support conclusions drawn by Hay & Walker (1989), whc found that delayed sowing of spring cereals caused acceleration or telescoping of crop development resulting in a tendency for lower maximum LAI. Khalifa *et al.* (1977) have also reported that wheat crop sown earlier and fertilized with higher dose of P exhibited the maximum LAI. Gutiérrez-Boem and Thomas

(1998) reported that lack of applied P decreased the rate of leaf appearance and therefore, the final number of leaves and leaf area per plant. Rodríguez *et al.* (2000) reported that P deficiency significantly reduced plant leaf area and dry weight production. Under mild P stress conditions up to 80% of the observed reduction in plant leaf area was due to the effects of P deficiency on leaf emergence and tillering. However, under severe P deficiency these authors could not explain the impact of P on such traits as other factors were involved.

It is concluded that higher dose of Phosphorus @120 kg P ha^{-1} and early sowing of wheat (October 25) produced maximum yield in the southern part of Punjab.

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