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Effects of Phosphorous on Growth and Yield of Snowpeas (*Pisum sativum var. Oregon sugar pod II*)

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ABSTRACT

Two field experiments were carried out concurrently at the Faculty of Agriculture, Field station farm, University of Nairobi in March-July 2000 (season I) and June-September 2000 (season II) to determine the effect of application of different levels of phosphorous (P) fertilizer on growth and yield of snowpea (*Pisum sativum* L. var. Oregon sugar pod II). The experiments were laid out in a complete randomized block design with three replicates. Four levels of P (0, 57, 114 and 171 kg P_2O_5 ha^{-1}) were applied as TSP (46% P_2O_5) at planting. Plant heights were measured at 31,38,45,58,71,84 and 97 DAS. Leaf area index and above- ground dry mass were determined at 29, 43, 63, 77 and 94 DAS. Harvesting of pods was done at 68, 72, 75, 79, 82, 86, 89, 93, 96 and 100 DAS. P fertilization resulted in significant ($P \leq 0.05$) increases in plant height, leaf area index, and total above ground dry matter accumulation in both seasons. Number of pods $plant^{-1}$ showed a quadratic trend with increasing P at 68, 89 and 93 DAS in season I. Linear and quadratic increases in number of pods $plant^{-1}$ were observed at 96 DAS and on total number of pods $plant^{-1}$. At 100 DAS, only linear increase was observed. Pod dry mass $plant^{-1}$ showed a quadratic increase at 68, 89, 93 and 96 DAS. At 100 DAS, linear increase in pod dry mass $plant^{-1}$ was observed. Linear and quadratic increases were observed in total pod dry mass $plant^{-1}$. P application did not affect both the number of pods and pod dry mass $plant^{-1}$ in season II probably because of the low amount of rainfall. Application of 57 kg P_2O_5 ha^{-1} resulted in dry pod yields of up to 9.75 tons ha^{-1} which is higher than the national dry mass averages of 5 to 6 tons ha^{-1}. It is therefore recommended that judicious levels of P be applied for growth of snowpeas.

Key Words: phoshorous, snowpeas, growth, yield

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INTRODUCTION

In Kenya, much attention has been focussed on production of French beans (*Phaseolus vulgaris* L.) although production of snowpeas (*Pisum sativum L.* var. Oregon sugar pod II) is becoming increasingly important. In small holdings, most of the fertilizer (40 to 60%) was applied on major cash crops (coffee, tea, and sugarcane) and, therefore, a comparatively small amount was applied on the large area of major food crops (Annon, 1988). Thus farmers do not apply fertilizers to food crops or do so at sub-optimal levels. Nutrient balance studies indicate that soils in small food-crop-based landholdings in the tropics frequently lose fertility as a result of greater export than input of nutrients. Losses of phosphorous (P) can be particularly detrimental to plant growth due to the inherently low plant available P in tropical soils. Also there is no biological process comparable to nitrogen (N) fixation by which P is added to soil (Annon, 1999). Phosphorous is generally needed in greater amounts in legumes than in non-legumes (Russells, 1973). Phosphorous is involved in reactions and processes required for accumulation and release of energy for cellular metabolism, seed formation and root development in crop plants (Terry and Ulrich, 1973; Kikby and Le Bot, 1994). An extensive root system provides a strong support (overcomes lodging) and a large surface area for the absorption of water and nutrients (Otani and Ae, 1996). Thus, P deficiency results in reduced plant growth, delayed maturity and a reduction in quality and quantity of crop yield.

Phosphorous requirement for optimal plant growth is in the range of 0.3 to 0.5% of the plant dry weight during the vegetative stages of growth (Marschner, 1986). In reproductive phase, level of P supply regulates the starch/sucrose ratio in the source leaves and the reproductive organs (Giaquinta and Quebedeaux, 1980). Presumably, this effect of P on partitioning is also responsible, in part, for the insufficient photosynthate supply to nodulated roots of P-deficient legumes and the occurrence of N deficiency as a dominant symptom in N-fixing legumes receiving inadequate levels of P (Marschner, 1986). Many tropical soils are inherently low in plant available P (Annon, 1999). Therefore, P deficiency is widespread due to the low P-status of the parent material, weathering, long-term anthropogenic mismanagement through imbalance between nutrient inputs and exports, and P loss by erosion and surface runoff (Annon, 1999). Hence the amount of available-P in the soil at any one time is relatively small compared to the amounts of other nutrients such as calcium (Ca), magnesium (Mg) and potassium (K). There exists a threefold P problem (Brady, 1990). First, the total- P level of soils is low. Second, the native P compounds are mostly unavailable for plant uptake, some being highly unavailable. Third, when soluble sources of P such as those in fertilizers and manure are added to soils, they are fixed or are changed to unavailable forms and in time react further to become highly insoluble forms e.g. apatites formed at soil pH above 7.0.

Mugwanja (1986) reported that P fertilizer application increase seed yield and oil concentration in sunflower. The highest seed yields were obtained with application of P at 31.5 and 63.0 kg ha^{-1} in "Issanka" and "H345" varieties, respectively. Fruit yields of sweet peppers increased from 11.17 to 35.22 tons ha^{-1} in the short rains in plants fertilized with 44 kg P ha^{-1} (Mwamba, 1987). The problem of soil fertility is widespread in all farming areas in the country due to continuous cropping, none application vis-a-vis application of inadequate levels of fertilizer and widespread poverty among rural farmers which makes fertilizers unaffordable. Athough research findings show that P fertilization may increase yields of different crops. Such studies have not been conducted in snowpea and hence the objective of this experiment was to determine the effect of different levels of P application on growth and yield of snowpea.

MATERIALS AND METHODS

Snowpea (*Pisum sativum* var. Oregon sugar pod II), produced by Royal Sluis and treated with Thirum (class 3) was used in this experiment. The experiment was conducted in two seasons at Kabete field station, University of Nairobi between March and July 2000 (season

I) and between June and September 2000 (season II). The site lies at latitude 1°15″S and longitude 36°44″E (Jaetzold and Schmidt, 1983) at an altitude of 1940m above sea level. The mean maximum and minimum temperatures are 23°C and 13°C respectively. The rainfall is bimodal, with long rains in March to June and short rains in October to December. The average rainfall is 1000 mm/year (Mburu, 1996).

The soils have been described as humic nitisols according to FAO/UNESCO (1984) classification, with Oxic paleustult as the soils' taxonomy USDA (1975) equivalent (Siderius 1976). The soil pH ranges between 5.2 to 7.2 in the topsoil and 5.2 to 7.7 in the subsoil. Available potassium (K), calcium (Ca), magnesium (Mg), and phosphorous (P) ranges from low to fairly high levels. Total soil N is about 0.26 % (Njuguna, 1997). In this study, soil pH was determined using a pH meter, soil N was determined by micro Kjeldahl method, available soil P was determined using mehlich's double acid method, CEC was determined using 1M KCL and 1M NH_4Oac and organic carbon was determined using Walkley-Black method. Other soil parameters e.g. sand, silt and clay fractions, available Ca, Mg, Na and K were not determined. The results of soil analysis in the top 0-15cm before the experiment was conducted are shown in Table 1.

Table 1: Results of laboratory analysis of the soil from the experimental sites (0-15cm) before planting

Parameter	Season 1	Season 2
pH (H_2O)	6.22	6.37
pH ($CaCl_2$)	5.36	5.39
%N	0.24	0.26
P (ppm)	17.9	18.7
%C	2.96	2.87
CEC (meq/100g)	14.3	14.1

pH (H_2O) = soil pH in water, pH ($CaCl_2$) = Soil pH in calcium chloride, %N = Percent nitrogen in the soil, P (ppm) = Soil phosphorous in parts per million , %C = soil organic carbon and CEC (meq/100g) = Cation exchange capacity.

The treatments consisted of four P levels i.e. 0, 57, 114 and 171 kg P_2O_5 ha^{-1} applied as TSP (46% P_2O_5) at planting. The experiment was laid out in a complete randomized block design. Each treatment was replicated three times. Each experimental plot measured 2 m x 3 m. The plant spacing was 0.1 m x 0.75 m within and between rows, respectively. Seeds were hand sown in furrows on 26th March 2000 in season I and on 3rd June 2000 in season II. In both seasons planted seeds took eight days to emerge. The crop received 357 mm and 82 mm of rainfall in season I and season II, respectively. Supplemental sprinkler irrigation was done at 58 DAS (22nd May 2000) in season I. In season II, it was done after planting, at 29, 44 and 58 DAS (3rd June and 1st, 16th and 30th July 2000) respectively (figure4). In both seasons, each duration of irrigation was three hours and this supplied approximately 10 mm of rainfall. The crop was trained three weeks after planting in both seasons to reduce lodging, improve air circulation around the plant, reduce the incidence of pests and diseases and improve light penetration through the canopy. Crop training was done using sisal strings tied from 0.2 m to 1.2 m above ground at 0.07m to 0.1m intervals.

Weed control was done through manual cultivation. Two weedings were done before the canopy closed. Powdery mildew was controlled by alternate application of Antracol and Bavistin at 40g/15 l and 40g/20 l of water, respectively. Insect pests were controlled using Diazol at 30ml/15 l of water. All chemicals were applied at 10 to 14-day interval up to maturity.

MEASUREMENTS

Plant heights were measured at 31,38,45,58,71,84 and 97 DAS, on three plants randomly selected from the middle three rows using a meter rule. Leaf area index (LAI) was determined at 29, 43, 63, 77 and 94 DAS using the specific leaf area method (Norman and Campbell, 1994). Using a cork borer, thirty 1-cm diameter discs were excised on 10 fully expanded leaves selected from three plants in each plot and put in 0.164m x 0.164m envelopes for drying. The remaining leaf portions were put in separate craft papers then oven dried (Model number TV80UL 508032, Memmert, Germany) to constant mass. The LAI was calculated using the following formula:

LAI = [LM x (LA discs / Lm discs)] x n

Where LM= leaf dry mass, LA discs = leaf area (m^2) of the discs, Lm discs = leaf dry mass (g) of the discs and n = number of plants per hectare.

Total above ground dry mass of snowpeas was determined on the three plants used for LAI determination. The leaves, leaf-discs, shoots and reproductive parts (pods, flowers and flower buds) were separately placed in craft papers and oven dried to constant mass. The snowpea pods were hand harvested from three plants randomly selected from three middle rows starting 68 DAS i.e. 1st June 2000 in season I and 9th Aug. 2000 in season II. Harvesting was done twice a week for upto five weeks by carefully picking the mature pods. Mature pods were described as being uniformly green, intact, clean (free from any disease or physiological disorders), flat with seeds not exceeding 4 mm in diameter and pod width of 1.5 to 2 cm (HCDA, 1996). The pods were then put in separate craft papers and oven dried after counting the number of pods.

STATISTICAL ANALYSIS

All the data collected was subjected to analysis of variance using GENSTAT 5 Release 3.2 statistical software (Lawes Agricultural Trust, Rothamsted Experimental Station, 1995). Treatment effects were analyzed by fitting orthogonal polynomial contrasts at $P \leq 0.05$ (Steel and Torrie, 1980).

RESULTS

Effects of P on growth

Application of P had a significant ($P \leq 0.05$) effect on plant height in both seasons (Figure 1). Plant height increased both linearly and quadratically with increasing P in all measurement durations in season I, except at 38 DAS. At 38 DAS, the increase was not statistically ($P \leq 0.05$) significant. At 38 and 97 DAS in season II, plant height increased both linearly and quadratically with increasing P levels. Although plant height increased with P application in other measurement durations, the increase was not statistically significant. Taller plants were observed in season I than in season II.

Application of P significantly ($P \leq 0.05$) influenced LAI in both seasons (Figure 2). At 43, 63 and 94 DAS in season I, LAI increased both linearly and quadratically with increasing P levels. Increase in LAI with increasing P levels in other measurement durations was not statistically ($P \leq 0.05$) significant. In season II, linear and quadratic increases were observed only at 43 and 77 DAS. At 94 DAS, only the quadratic response was observed, while the increase in LAI with increasing P levels was not significant in the other measurement durations. LAI increased up to 77 DAS before decreasing in both seasons. Higher values of LAI were observed in season I than in season II.

Phosphorous application significantly ($P \leq 0.05$) affected TDM accumulation in snowpeas in both seasons (Figure 3). At 29 DAS in season I, increase in TDM with P level was not statistically ($P \leq 0.05$) significant. However, dry mass accumulation increased linearly and quadratically with increasing P levels in all other measurement durations in both seasons. Season I peas had higher dry mass accumulation than those of season II. After 77 DAS, a decrease in dry mass accumulation in snowpeas occurred in both seasons.

Effects of P on yield

Application of P resulted in a quadratic response in number of pods plant^{-1} at 68, 89 and 93 DAS in season I. (Table 2). Linear and quadratic increases in number of pods plant^{-1} with increase in P were observed at 96 DAS. At 100 DAS, only linear increase was observed. Overall number of pods per plant increased linearly and quadratically with increase in P. No effect was observed in season II. Pod production increased inconsistently from 68 to 89 DAS and then decreased in both seasons.

Table 2: Effects of different levels of P on number of pods plant^{-1} in season 1 (March-June 2000) and II (June-Sept. 2000)

Season I											
P Level	68	72	75	79	82	86	89	93	96	100	Total
P0	2.33	6.33	6.56	6.11	6.00	5.67	6.00	4.67	2.67	2.11	48.44
P1	3.78	6.89	7.44	6.67	6.89	7.33	8.22	6.56	5.22	2.89	59.89
P2	2.89	6.56	6.89	7.56	7.11	6.33	7.33	5.00	4.56	2.33	56.56
P3	2.56	6.67	6.11	7.22	7.00	6.22	6.78	5.44	3.56	2.78	54.33
Trend	Q*	NS	NS	NS	NS	NS	Q*	Q*	L*Q*	L*	L*Q*
Season II											
P0	3.89	5.89	6.22	6.33	7.11	7.11	7.78	4.11	2.67	2.00	53.11
P1	3.89	5.67	7.00	7.11	7.89	7.22	7.89	3.78	2.67	1.89	55.00
P2	4.11	5.78	6.89	6.67	8.11	6.89	7.33	4.22	3.22	2.00	55.22
P3	4.00	6.00	6.67	7.44	7.33	6.00	6.67	3.56	2.11	1.78	51.56
Trend	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

P0, P1, P2, and P3 = 0, 57, 114, and 171 kg P_2O_5 ha^{-1}, NS= Not significant, *= Significant ($P \leq 0.05$), L = Linear, Q = Quadratic

Pod dry mass plant^{-1} showed a quadratic trend at 68, 89, 93 and 96 DAS following the application of P in season I. (Table 3). At 100 DAS, a linear increase in pod dry mass plant^{-1} was observed. The total pod dry mass increased both linearly and quadratically with increasing P in season I. No effect was observed in season II. Pod dry mass was high in season I than in season II.

Table 3: Effects of different levels of P application on pod dry mass plant^{-1} in season 1 (March-June 2000) and II (June-Sept. 2000)

Season I	*Days after sowing*										
P Level	68	72	75	79	82	86	89	93	96	100	Total
P0	0.58	1.53	1.57	1.48	1.45	1.34	1.43	1.16	0.67	0.53	11.74
P1	0.92	1.67	1.80	1.65	1.69	1.78	2.01	1.43	1.26	0.70	14.61
P2	0.70	1.59	1.68	1.85	1.73	1.53	1.78	1.24	1.11	0.56	13.77
P3	0.63	1.62	1.47	1.74	1.68	1.47	1.59	1.33	0.88	0.71	13.12
Trend	Q*	NS	NS	NS	NS	NS	Q*	Q*	Q*	L*	L*Q*
Season II											
P0	0.79	1.19	1.27	1.27	1.43	1.45	1.56	0.85	0.57	0.41	10.79
P1	0.81	1.15	1.41	1.43	1.58	1.45	1.58	0.78	0.55	0.39	11.13
P2	0.84	1.16	1.41	1.35	1.64	1.40	1.49	0.86	0.67	0.42	11.24
P3	0.82	1.20	1.35	1.50	1.47	1.21	1.36	0.74	0.45	0.37	10.47
Trend	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

P0, P1, P2, and P3 = 0, 57, 114, and 171 kg P_2O_5 ha^{-1}, NS= Not significant, *= Significant ($P \leq 0.05$), L = Linear, Q = Quadratic

DISCUSSION

Effects of P on growth

Most acid tropical soils have low soil P status of less than 200 ppm (Cabala and Fasbender, 1970). Such acid soils occur as a result of leaching of exchangeable bases occurring due to high rainfall experienced in tropical areas (FAO, 1986). These soils can convert large quantities of applied P fertilizer into non-available forms by adsorption into clay colloids. The amount of P available to plants has to be raised if the productivity of these soils is to be improved. Apatite is the most common primary mineral carrier of P (Nyandat, 1981). It does not occur commonly in Kenyan soils, where P deficiency is a usual phenomenon requiring amelioration through application of fertilizers or manure.

Adequacy of P nutrition is associated with satisfactory root development (Smarrt, 1976). Phosphorous stimulates the production of a stronger and more vigorous root system, which could provide better anchorage of the plants in the soil, explore the soil for and absorb more nutrients including N and water from the soil. Soil available P at the site of this study was 17.9 and 18.7 ppm in season I and season II, respectively. Soil P in the range of 0 to 20 ppm determined using Mehlich method is categorised as low (Annon, 1991). Therefore, response to added P was expected.

In the present study, P fertilization led to significant ($P \leq 0.05$) increase in growth and development of snowpeas as measured by plant height, LAI, and above ground dry matter accumulation with time. Similar observations have been made in beans (Mbugua, 1983) and in runner beans (Kahuro, 1991) where application of P led to increased growth as measured by above ground dry matter accumulation with time. Mahatanya (1977), reported that plant height, pods plant^{-1}and pod weight increased with increased level of P. Similarly, plant height in garden-pea increased with P application (Shukla *et al*., 1993).

Abdel-Hafez (1966) reported that the addition of P to the soil enhanced high densities of acid producers. Phosphorous dissolvers in the rhizosphere of legumes also increased rendering soil P more available for plant uptake. Ssali (1988) reported that even with inoculation with N-fixing microbes, P may be necessary for common beans to nodulate effectively. It is possible that P treated plants may have benefited more from N nutrition due to enhanced nodulation thereby increasing the dry matter accumulation.

Growth and development in season II was low compared to season I. The discrepancy may be attributed to drier conditions in season II which received a total of 82 mm of rainfall compared to 357 mm in season I (Appendix 1). The rainfall received was lower than that required for legumes, e.g. beans require at least 300-380mm of rainfall during the growing season (Kay, 1979). Although supplemental irrigation was done, moisture supplied could have been insufficient to meet the crops' requirement hence subjecting it to mild water stress. Effectiveness and availability of applied P is directly proportional to moisture content of the soil (Tisdale *et al*., 1990). When moisture is high, P uptake is high. When moisture is low, P uptake is also low.

Effects of P on pod yield

Development of fruit and seed requires adequate and balanced supplies of essential nutrient elements (Smarrt, 1976). If these are imbalanced or inadequate, widespread abortion of pods and seeds will occur. Early in plant life, adequate supply of P is needed for laying down the primordia for its reproductive parts (Tisdale *et al*., 1990).

In the present study, P application significantly ($P \leq 0.05$) increased the number of pods and pod dry mass plant^{-1} at 68, 89, 96 and 100 DAS in season I. Total number of pods/plant and total pod dry mass plant^{-1} also increased with P application. Similarly, Mahatanya, (1977); Keya and Mukunya, (1979) also observed increased yields of beans (*Phaseolus vulgaris*) due to increasing levels of application of P fertilizer. In pigeonpea, Singh *et al*., 1976, observed increased grain yields with increase in P. The highest yields were obtained with application of 43.6 kg P ha^{-1}.

The national average dry yield of snowpeas is 5 to 6 tons ha^{-1} (e.g. HCDA, 1996). Our study showed that these yields would be improved with P fertilization. Application of 57 kg P_2O_5 ha^{-1} resulted in yields of up to 9.75 tons ha^{-1}. This level is lower than the approximately 114 kg P_2O_5, applied by farmers at planting. It is therefore recommended that judicious levels of P be applied for growth of snowpeas.

It has been established that P is vital in phytohormone balance (Marschner, 1986). This is particularly true of the relationship between P deficiency and decrease in number of flowers and delay in flower initiation. It is possible that P will lead to increased yield through increased pod production resulting from increased growth. Exactly how P led to increased pod yield was not determined in this study. Mahatanya (1977) suggested that increased bean seed yield following P application was partly by promoting pod production.

The results of season II showed that P application had no effect on yields of snowpeas. Mbugua, (1983) had observed non-significant increases in pod dry matter and number of pods $plant^{-1}$ in beans. The author suggested that the rate of pod abscission could have been higher in fertilizer treated plants than in control plants making the number of pods more uniform in all treatments. Ogombe, (1978) had suggested that lack of response to increasing P level in number of pods $plant^{-1}$, seeds pod^{-1} and 100-seed mass was probably due to internal plant factors such as hormones, which are not affected by P fertilization. However, Chui, (1989) observed that P application increased bean seed yield when the season had a favourable amount and good distribution of rainfall. Hence, lack of response to P in season II could be attributed to flower abortion resulting from the low moisture supplies during flowering. It is therefore apparent that benefits of using P to promote production of snowpeas would be realized only during periods of high soil moisture contents.

RECOMMENDATIONS

The results of the present study show that application of P increases growth and development of snowpeas. However, this occurs best when the crop is supplied with sufficient soil moisture. In this study, low moisture content that occurred during growth of snowpeas in season II could probably have led to decreased P uptake and hence reduced plant growth and development. For reproducibility of the results, further work needs to be done in the various agroecological zones due to site specificity of climatic factors and edaphic environment.

Where economically justified, future research should incorporate farmers to facilitate adoption of the new research findings.

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APPENDICES

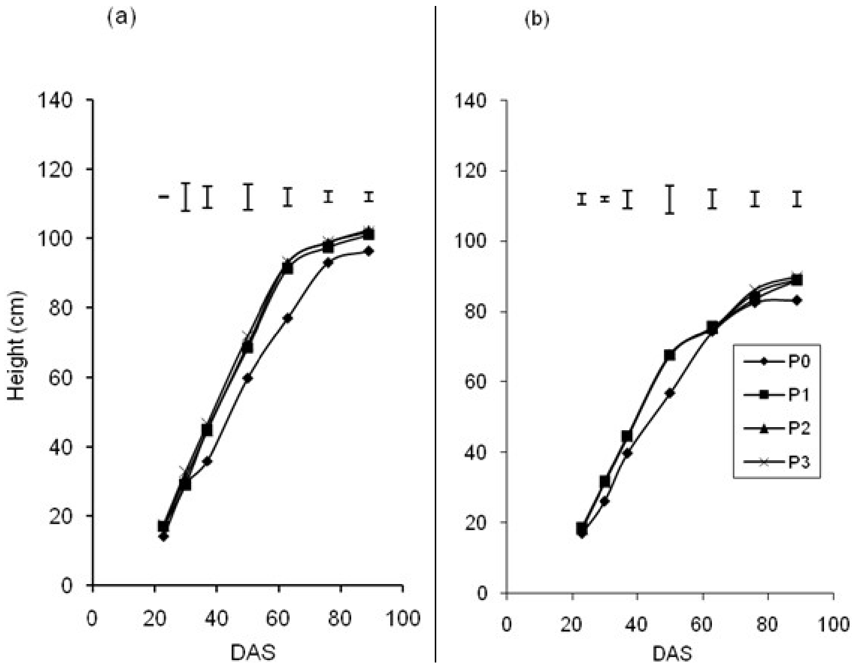

Figure 1: Effects of different levels of P on plant height in snowpeas in season 1 (a) and season 2 (b), (DAS= Days after sowing, P0= 0 , P1= 57,P2= 114 and P3= 171kg P_2O_5 ha^{-1},Vertical bars = Lsd bars at P = 0.05).

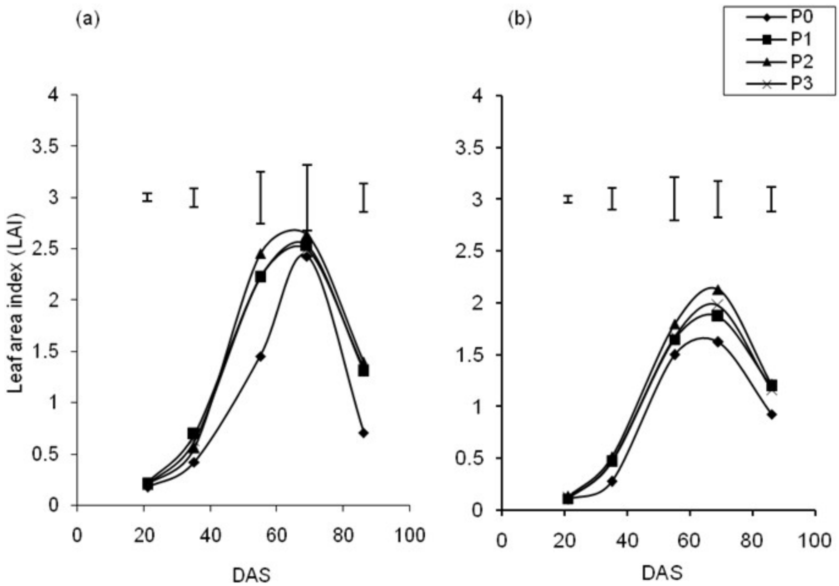

Figure 2: Effects of different levels of P on leaf area index (LAI) in snowpeas in season 1 (a) and season 2 (b), (DAS= Days after sowing, P0= 0,P1= 57, P2 = 114 and P3=171kg P_2O_5 ha^{-1}, Vertical bars = Lsd bars at P= 0.05).

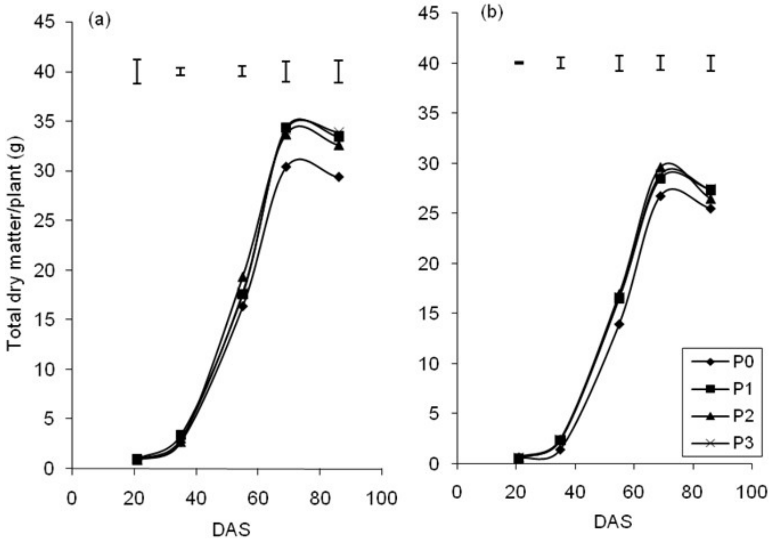

Figure 3: Effect of different levels of P application on total above ground dry matter (g/plant) accumulation in snowpeas in season 1 (a) and season 2 (b), (DAS = Days after sowing, P0= 0,P1= 57, P2= 114 and P3= 171kg P_2O_5 ha^{-1}, Vertical bars = Lsd bars at P = 0.05)

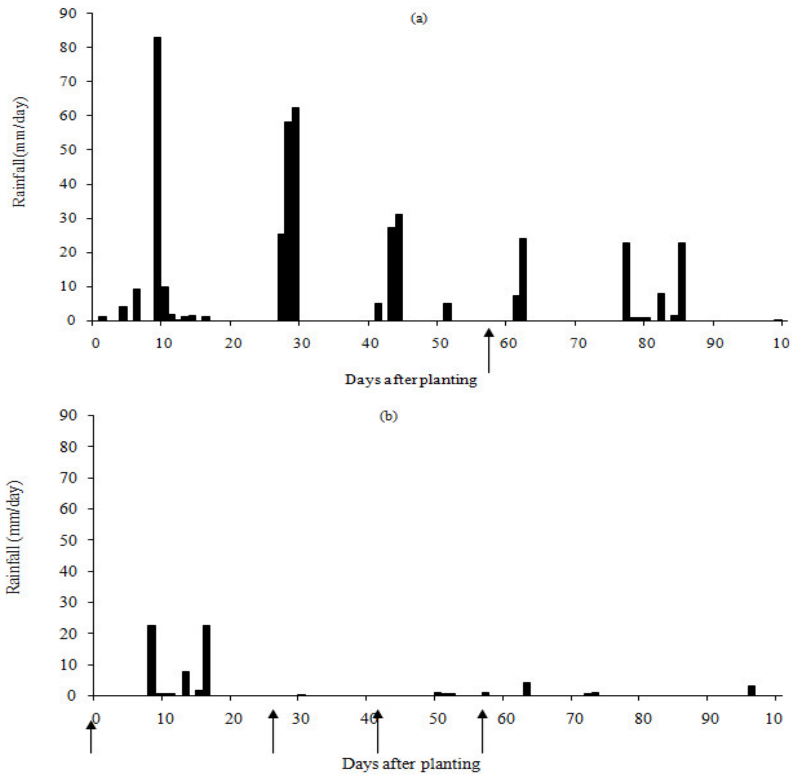

Figure 4: Daily rainfall (mm/day) in season I (a) and season II (b).

→ = Irrigation. Each irrigation supplied approximately 10mm of rainfall.

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