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Performance of chickpea (*Cicer arietinum* L.) cultivars and estimation of economic optimum doses of phosphorus in an Alfisol of West Bengal

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ABSTRACT

Harnessing maximum yield through varietal preference and adequate nutrition is the key to agricultural production systems. Field experiment was conducted at the "AB -Block Farm", BCKV, West Bengal for two consecutive rabi seasons of 2012-13 and 2013-14 to evaluate three chickpea cultivars ('Anuradha', 'PUSA-1003' and 'DCP-92-3') for their performance under varied P_2O_5 levels(0, 20, 40, 60, 80 kg P_2O_5 ha^{-1}) and to estimate the economic optimum level of P_2O_5 for seed yield. The trials were laid out in a split-plot design with the cultivars allotted to main plots and P2O5 levels in sub-plots. The highest mean dry matter accumulation per plant of 0.96 ,1.42 ,4.26 and 11.21 g in root, leaves, stem and pod occurred in the 'DCP -92-3' cultivar. The contribution of pods to total dry matter production (TDM), respectively was 63.2% in the DCP-92-3 cultivar. The mean higher dry matter (18.4 g $plant^{-1}$) and seed yield (1425 kg ha^{-1}),were obtained with 80 kg P_2O_5 ha^{-1}. The agronomic efficiency declined with the increase in P_2O_5 levels. By using the developed function relationship ($Y=964.5+13.13x-0.093x^2$) i.e. quadratic, between seed yield of chickpea and applied levels of P_2O_5 the estimated optimum and economic doses of P_2O_5 were 70.6 and 66.46 $kgha^{-1}$ respectively. The response at economic optimum dose of P_2O_5 was 6.67 kg seed yield per kg P_2O_5 applied.

Keywords: Chickpea, cultivar, phosphorus, optimum, economic dose.

In West Bengal, from an area of 0.02 m ha about 0.02 m t of chickpea is produced with an average yield of 1000 kg ha^{-1} (http:agricoop.nic.in_/imagedefault/trade/pulses%20_profile.doc). Productivity of this crop is much below than national average, and the prime factor is the non-judicious use of fertilizers. Legumes generally require higher amount of P_2O_5 as the process of symbiotic nitrogen fixation consumes a lot of energy (Schulze *et al*., 2006). Apart from being a constituent of certain malic acids, phosphorus stimulates root, seed and fruit development as well as aids in vital metabolic functions (Singh *et al*., 2012). The yield potential of chickpea is manifested through total biomass produced which is the outcome of the integration of metabolic reactions in plant. Metabolic processes of chickpea are governed by both internal *i.e.* genetic makeup of the plant and external factors such as climate and edaphic environment. In general, the use efficiency of phosphorus is low while the phosphatic fertilizers are becoming costly. Therefore, economic and judicious use of this precious input assumes great importance. In the region of gangetic alluvial soils in West Bengal having higher cropping intensity, there is a need to constantly refine nutrient management practices for realization yield potential as chickpea particularly under rainfed situation. This study was initiated to investigate the effect of phosphorus at different levels on dry matter distribution, seed yield and agronomic efficiency of some chickpea cultivars. The study also aims to ascertain the optimum and economic levels of P2O5 for chickpea grown in an Alfisol of West Bengal.

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MATERIALS AND METHODS

Field experiments were conducted at the District Seed Farm (AB Block), Bidhan Chandra Krishi Viswavidyalaya, West Bengal during the two successive *rabi* seasons of 2012-13 and 2013-14 to study the effect of P2O5 on growth and yield of chickpea and to determine economic optimum dose. The soil was sandy having pH 6.2,organic carbon 0.56 %, P_2O_5 28.65 kg ha^{-1} and K_2O 138 kg ha^{-1}. The experiment included 15 treatments combinations having three chickpea cultivars ('Anuradha', 'PUSA-1003' and 'DCP-92-3') and five levels of P_2O_5 (0, 20, 40, 60, 80 kg ha^{-1} replicated thrice. The treatments are arranged in a split-plot design where P_2O_5 levels were allotted in main plot and cultivars in sub-plots. Each plot size was 3x4 m. All the plots received blanket applications of 20 kg N and 40 kg K_2O ha^{-1} in the form of urea and muriate of potash, respectively. Seeds were sown on November 9 and 26 in the year 2012 and 2013 respectively with 30cm x 20 cm spacing after proper land preparation by cultivating 2 times followed by planking. Entire P_2O_5 fertilizer was applied as basal dose in all the plots. At maturity, 5 representative samples from each plot were collected and partitioned into root, leaves, stem, and pod, which were then dried at 70°C till constant weight was obtained. The completely dried samples were weighed and the dry weights were expressed in g plant^{-1}. The yield plot^{-1} was recorded from plant samples in an area, excluding two border rows and then converted into yield ha^{-1}. The cultivars 'Anuradha' and 'DCP 92-3' were harvested on April 2, 2013 and April 11, 2014,while the cultivar 'PUSA-1003' was harvested on April 2, 2013 and April 5, 2014. The data obtained were analyzed statistically by SPSS software (ver 11.0). The treatment means were separated using Fisher's critical differences (Gomez and Gomez,1984). The Agronomic efficiency crop yield increase per unit kg grain kg^{-1} nutrient was computed by the formula: AE= $(Y_P-Y_O)/A_P$; where, Y_p=Yield of chickpea at applied P_2O_5 level; Y_o=Yield of chickpea without P_2O_5 application; A_p=amount of P_2O_5 application (Prasad and Van Keulen, 2003).

In determining optimum phosphorus dosage, the model that defines the yield-fertilizer relation best is preferred. Linear, quadratic, square root and Mitscherlich models were tried in this study, and the relationship between yield and fertilizer dosage was found to be defined by the quadratic model in the best way.

Quadratic model:

Y is formulated as: $Y = a + bx + cx^2$; Y = seed yield (kg ha^{-1}); X = the dosage of the P_2O_5 applied (kg ha^{-1}) where, a, b and c are the parameters of the model.

The economic decision rule for optimizing input is a function of three variables: the marginal contribution of the input to output as measured through production function and the prices of input and output. Differentiating Y with respect to P_2O_5doses of the regression model give the doses for maximum yield which is estimated by the equation $P_{max} = - b/2c$. The equation for economic dose for maximum profit is $E = 1/2c\ (Ps/P_{NU} – b)$ where Ps and P_{NU} are prices of chickpea seed and P_2O_5 respectively (Colwell, 1994). The unit price of chickpea seed was taken as Rs 33 kg^{-1}as the two years average value. The per unit price of P_2O_5, averaged over two years, was Rs 43.9 kg^{-1}. The response to economic optimum dose of P_2O_5 was computed by using the equation: REOD= $(Y_{opt.}-Y_{cont.})/X_{opt.}$; where $Y_{opt.}$= Yield computed at economic optimum dose; $Y_{cont.}$=Yield in control plot; $X_{opt.}$= Economic optimum dose (Islam *et al.*, 2012).

RESULTS AND DISCUSSION

The dry matter distribution in various plant parts at harvest of tested chickpea cultivars with varied P_2O_5 levels is presented in table -1, and significant variation in dry matter distribution between the cultivars was observed. The significantly higher dry matter accumulation was found in 'DCP-92-3' while lowest in 'Anuradha'. The of two years pooled dry matter accumulation in root, leaves, stem and pod was to the tune of 31.68, 46.86, 140.58 and 369.60 g m^2 for 'DCP-92-3' respectively. The other two tested cultivars followed the order of mean dry matter accumulation as 'PUSA 1003' (0.25.41 in root, 41.91 in leaves, 120.12 in stem and 274.56 g m^2 in pod) > 'Anuradha' (22.61 in root, 37.95 in leaves, 109.56 in stem and 198.66 g m^2 in pod). The total dry matter production (TDM) was significantly higher in 'DCP-92-3' during both the years of experimentation (pooled, 585.42 g m^2). Next in order of TDM was 'PUSA-1003' (pooled, 459.03 g m^2) and the lowest was observed in 'Anuradha' (pooled ,368.61 g m^2). Such differences in dry matter distribution and production might be related to the respective genetic makeup of the chickpea cultivars resulting in differences in partition and migration of photosynthates (Ahmed and Badr, 2009). In 'DCP-92-3', the mean contribution of pods to TDM was 63.2%, which was higher than 'PUSA-1003' (59.8%) and 'Anuradha' (54.8%). This clearly indicates that 'DCP-92-3' was more efficient in translocating the major portion of dry matter from source to sink.

Application of P_2O_5 showed significant differences on dry matter distribution at harvest in different plant parts. With each incremental dose of P_2O_5 from 0 to 80 kg ha^{-1} there was concomitant increase in dry matter accumulation (Table 1). The significantly higher dry matter accumulation occurred with the application of 80 kg ha^{-1} during both the years. Two years' pooled dry matter accumulation due to 80 kg P_2O_5 ha^{-1} application was 36.63 in root, 55.44 in leaves, 158.73 in stem and 356.73 g m^2 in pod. Mansur *et al*. (2009) observed that P2O5 application did not show any significant effect on dry matter accumulation in leaves but that in stem, pod and TDM differed significantly. The pooled TDM (g m^2) was in the order of 80 kg P_2O_5 ha^{-1} (607.53) > 60 kg P_2O_5 ha^{-1} (556.71) > 40 kg P_2O_5 ha^{-1} (505.89) > 20 kg P_2O_5 ha^{-1} (390.06) > control (303.60). The TDM is largely a function of photosynthetic surface which was favourably influenced by phosphorus fertilization. Jain *et al*. (2003) and Das *et al*.(2008) also reported higher accumulation of dry matter with application of P_2O_5. The mean percent contribution of pods to TDM was highest with the application of 40 kg P_2O_5 ha^{-1} (61.2%). Further increasing the dose of P_2O_5 application reduced the mean percent contribution of pods to TDM (59.5% in 60 kg P_2O_5ha^{-1} and 58.7% in 80 kg P_2O_5 ha^{-1}).

Table 1: Dry matter distribution pattern in chickpea cultivars at harvest as influenced by levels of P_2O_5

Treatments	Root			Leaves			Stem			Pod			Total dry matter (TDM) production			Mean contribution of pods to TDM (%)
	Year 1	Year 2	Pooled	Year 1	Year 2	Pooled	Year 1	Year 2	Pooled	Year 1	Year 2	Pooled	Year 1	Year 2	Pooled	
Cultivars																
Anuradha	21.78	23.43	22.61	32.34	43.23	37.95	106.59	112.53	109.56	193.05	203.94	198.66	354.09	383.46	368.61	53.9
Pusa-1003	23.76	26.73	25.41	36.30	47.52	41.91	116.82	123.75	120.12	261.36	282.15	274.56	438.24	480.15	459.03	59.8
DCP-92-3	30.36	33.00	31.68	42.24	51.48	46.86	135.63	145.53	140.58	356.40	374.88	369.60	565.95	604.89	585.42	63.2
SEm (±)	**0.4**	**0.5**	**0.3**	**0.4**	**1.0**	**0.6**	**1.4**	**3.9**	**2.1**	**4.8**	**5.6**	**4.8**	**5.2**	**3.6**	**3.1**	**1.1**
LSD (0.05)	**1.6**	**1.9**	**1.2**	**1.5**	**4.0**	**2.4**	**5.6**	**15.2**	**8.4**	**18.9**	**22.0**	**18.7**	**20.5**	**14.2**	**12.1**	**4.3**
P_2O_5 levels (kg ha^{-1})																
P0	15.84	16.83	16.50	28.05	31.02	29.37	70.95	78.87	74.91	159.06	164.34	161.70	291.72	315.48	303.60	53.3
P20	21.78	25.41	23.76	30.69	42.57	36.63	101.97	111.21	106.59	217.14	229.02	223.08	371.91	408.21	390.06	57.2
P40	24.75	28.38	26.40	35.31	45.87	40.59	128.37	130.35	129.36	301.95	317.13	309.54	490.38	521.73	505.89	61.2
P60	28.38	30.69	29.70	41.58	55.11	48.18	144.21	151.14	147.84	324.39	337.59	330.99	538.56	574.86	556.71	59.5
P80	36.30	37.29	36.63	48.84	62.04	55.44	152.79	164.67	158.73	350.79	362.34	356.73	588.72	626.34	607.53	58.7
SEm (±)	**1.0**	**0.7**	**0.6**	**0.6**	**1.6**	**0.9**	**1.8**	**5.9**	**3.1**	**6.0**	**9.0**	**4.8**	**7.3**	**10.4**	**5.6**	**1.3**
LSD (0.05)	**2.9**	**2.1**	**1.8**	**1.8**	**4.6**	**2.6**	**5.3**	**17.1**	**9.1**	**17.5**	**26.2**	**14.0**	**21.4**	**30.4**	**16.4**	**NS**
Cultivar × P																
SEm (±)	**1.7**	**1.2**	**1.1**	**1.1**	**2.7**	**1.5**	**3.1**	**10.1**	**5.4**	**10.4**	**15.5**	**8.3**	**12.7**	**18.0**	**9.7**	**2.3**
LSD (0.05)	**NS**	**3.6**	**3.1**	**3.1**	**NS**	**4.4**	**9.2**	**NS**	**NS**	**30.3**	**45.3**	**24.2**	**37.1**	**52.7**	**28.4**	**NS**

Note: NS = Not significant

The relationship obtained between dry matter accumulated in different plant parts and seed yield of chickpea is produced in table- 2. The models which defined the respective dry matter and seed yield best among the linear, second order polynomial (quadratic), logarithmic and exponential functions are given. It was observed that while the roots, leaves and stems showed exponential relationship, the pod and total dry matter showed quadratic relationship with seed yield. About 84.5, 74.5 and 83.3% variation in seed yield could be explained by dry matter accumulation in roots, leaves and stems, respectively. The exponential function suggests that constant changes in the dry matter accumulation in root, leaves and stem give the same proportional change in seed yield. The dry matter accumulation in pod and TDM were responsible for 91.4 and 91.6% variation respectively in seed yield of chickpea.

Various physiological, biochemical and phonological processes occurring in the plant system determine the seed yield, and the cultivar 'DCP-92-3' gave higher yield (Table 3). The seed yield of 'DCP-92-3' was higher and varied significantly from other cultivars during both the years (1381 and 1480 kg ha^{-1} in 2013 and 2014, respectively). The next in order was 'PUSA-1003' producing a mean seed yield of 1279 kg ha^{-1} followed by 'Anuradha' (1086 kg ha^{-1}). The cultivars 'DCP-92-3' and 'PUSA-1003' produced 32 and 18 % more seed yield than 'Anuradha'. The seed yield of

Table 2: Regression equations between dry matter accumulation and seed yield of chickpea

Parameter	Regression equation	R^2(adj) value
Root dry wt. vs seed yield	$Y=0.157e^{0.001x}$	0.845
Leaves dry wt. vs seed yield	$Y=0.385e^{0.000x}$	0.745
Stem dry wt. vs seed yield	$Y=0.798e^{0.001x}$	0.833
Pod dry wt. vs seed yield	$Y=20.49-0.034x+0.00002x^2$	0.914
Total dry matter vs seed yield	$Y=20.88-0.033x+0.00002x^2$	0.916

Note: x = Root dry wt; leaves dry wt; stem dry wt; pod dry wt; total dry matter

Table 3: Yield and agronomic efficiency of chickpea cultivars at different P_2O_5 rates

Treatments	Seed yield (kg ha^{-1})			Mean increase over control for P_2O_5 application(%)	Mean agronomic efficiency(kg seed kg^{-1} nutrient applied)
	Year 1	Year 2	Pooled		
Cultivar s					
Anuradha	1050	1121	1086		
Pusa-1003	1263	1295	1279		
DCP-92-3	1381	1480	1430		
SEm(±)	**14.94**	**4.36**	**6.28**		
LSD (0.05)	**58.65**	**17.11**	**24.64**		
P_2O_5 levels (kg ha^{-1})					
P 0	939	971	955	-	-
P 20	1186	1230	1208	26.45	12.63
P 40	1294	1390	1342	40.46	9.66
P 60	1350	1440	1395	46.03	7.33
P 80	1388	1463	1425	49.22	5.88
SEm (±)	**15.15**	**5.05**	**7.69**		
LSD (0.05)	**44.2**	**14.73**	**22.45**		
Cultivar × P					
SEm (±)	**26.23**	**8.74**	**13.32**		
LSD (0.05)	**NS**	**25.51**	**38.89**		

NS = Not significant

chickpea varied significantly with the application of P_2O_5 (Table 3). There was significant increase in seed yield with increase in P_2O_5 levels, except between 60 kg and 80 kg P_2O_5 ha^{-1} during 2013. The mean seed yield increased from 955 to 1425 kg ha^{-1} as the P_2O_5 rate was increased from 0 to 80 kg ha^{-1}. The mean per cent increases in seed yield over control due to 0, 20, 40, 60 and 80 kg P_2O_5 ha^{-1} were 26.45, 40.46, 46.03 and 49.22%, respectively. Such increase in seed yield of chickpea with higher rates of P_2O_5 application up to 60 kg/ha was reported by Bahadur *et al*. (2002) and Singh *et al*. (2001). The increment in seed yield of chickpea with increase in P_2O_5 levels might be attributed to the physiological role of P_2O_5 on the meristematic activity of plant tissues enhancing plant growth and also its function as a part of enzyme system having a vital role in the synthesis of other food from carbohydrate (Ahmed and Bard, 2009).

The mean agronomic efficiency (AE) ranged between 5.88 and 12.63 kg seed kg $P_2O_5^{-1}$ applied (Table 3). The more the levels of P_2O_5 applied the AE declined. Such reduction is AE with higher nutrient application rates was also reported by Kumar *et al.* (2011) and Chakraborty (2013).

In this study the model which defines the relation between using P_2O_5 and yield of chickpea was obtained using the quadratic function ($Y=964.5+13.13x-0.093x^2$, $R^2=0.993$). The co-efficient of determination representing $R^2=0.93$ expressed the yield response of chickpea about 93% due to P_2O_5 application (Fig.1). The results are in agreement with Islam *et al.* (2012).

The optimum and economic levels of P_2O_5, as computed by the developed quadratic function, were 70.6 and 66.46 kg ha^{-1} with predicted yields of 1428 and 1426 kg ha^{-1} respectively. The response at economic optimum dose 6.67 kg seed yield per kg P_2O_5 applied. Islam *et al*. (2012) also predicted and estimated by using functional relationship in chickpea. The two years experimental results indicate that the cultivar 'DCP-92-3' was the best yielder, and P_2O_5 application @ 80 kg ha^{-1} could be the choice for higher seed yield. Predictions suggest that the optimum P_2O_5application would be 70.6 kg ha^{-1} for obtaining higher yield while 66.46 kg ha^{-1} would fetch higher profit in the Alfisol of West Bengal.

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