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Influence of varying phosphorus rates on productivity, resource-use efficiency and profitability of chickpea (*Cicer arietinum* L.) in Ghazni province of Afghanistan

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ABSTRACT

Chickpea (*Cicer arietinum* L.) is one of the major pulse crops having considerable importance as food, feed and fodder. It is responsive to phosphorus (P) application, but no recommendation on P fertilization in chickpea is available for Afghanistan. Thus, to find out the optimum rate of P application in chickpea, a field experiment was conducted during spring season of 2017 at Agronomy Research Farm, Agriculture Faculty of Ghazni University, Ghazni, Afghanistan. It is characterized by cold and semi-arid climate. The experiment was laid out in a randomized complete block design with four replications. The treatments included five P application rates, 0, 15, 30, 45 and 60 kg P_2O_5 ha^{-1}. The results revealed that application of increasing rates of P significantly increased root nodule number, productivity, profitability and resource-use efficiency. With successive increase in levels of P there was a significant increase in root nodule count, grain yield, straw yield, gross returns, net returns, B:C ratio, water-use efficiency, production efficiency, monetary efficiency, total energy output, net energy benefit, energy-use efficiency and energy productivity up to 60 kg P_2O_5. However, maximum root nodule count (27.1), seed yield (2.04 t ha^{-1}), straw yield (4.05 tha^{-1}), grass returns (2,33,941 Afn. ha^{-1}), net returns (1,84,516 Afn. ha^{-1}), benefit: cost ratio (3.84), irrigation water-use efficiency (9.05 kg ha^{-1} mm^{-1}), production efficiency (19.4 kg ha^{-1} day^{-1}), monitory efficiency (1757.3 Afn. ha^{-1} day^{-1}), total energy output (91,360 MJ ha^{-1}), net energy output (79,810 MJ ha^{-1}), energy- use efficiency (7.91) and energy productivity (0.176 kg MJ^{-1}) were recorded with 60 kg P_2O_5 ha^{-1}, which were significantly greater than control, 15 and 30 kg P_2O_5 ha^{-1}, but these parameters were at par with 45 kg P_2O_5 ha^{-1}.

Key words: Chickpea, energy, profitability, production efficiency, resource-use efficiency

INTRODUCTION

Pulses occupy a unique position in farming all over the world. Among the pulse crops chickpea (*Cicer arietinum* L.) is the third most widely grown grain legume in the world after bean and soybean (Dass et al., 1997; Soltani et al., 2006; Dass, 2008). About 70% of world's chickpea production comes from Asia. Chickpea is predominantly grown in cool, dry periods on receding soil moisture. It is known to have originated in western Asia (probably eastern Turkey) (Hussen et al., 2013). It is also a major pulse crop grown in Afghanistan for food and also used as a feed for animals. It is predominantly grown as an irrigated crop though in some parts of the country, it is grown under rainfed conditions also. Chickpea is mostly consumed in the form of processed whole seed (boiled, roasted, parched, fried, steamed, sprouted, etc.). Chickpea is a good source of protein (18–22%), carbohydrate (52–70%), fat (4–10%), minerals (calcium, phosphorus, iron) and vitamins (Dass et al., 2008; Choudhary, 2014).

It is a helpful source of high quality protein in the diets of millions of people in developing countries who cannot afford animal protein for balanced nutrition (Zia Ul-Haq et al., 2007). Grains are also very high in dietary fiber and hence a healthy source of carbohydrates for persons with insulin sensitivity or diabetes (Deppe, 2010). Further, it is an excellent animal feed as its straw has good forage value (Prasad, 2012). As it is used as feed for livestock, thus it has a significant role in farming systems (Singh, 1997). It has multipurpose use and ability to grow under the condition of low fertility and varying conditions of soil and climate (Nawange et al., 2011). Chickpea is not only a source of dietary protein but it also helps to enriches the soil fertility due to its nitrogen fixing capability (Dotaniya et al., 2014).

Among the fertilization especially that of P has a key role on yield of chickpea (Dass et al., 1997; Dass, 2008). In many soil types, P is the most limiting nutrient for the production of crops (Jiang et al., 2006; Pooniya et al., 20015; Rana et al., 2018) that plays primary role in many of the physiological processes. Legumes generally have higher P requirement because the process of symbiotic N fixation consumes a lot of energy (Schulze et al., 2006). Some specific growth factors that have been associated with P are stimulated root development, increased stalk and stem strength, improved flower formation and seed production, more uniform and earlier crop maturity, increased N-fixing capacity of legumes, improvements in crop quality, and increased resistance to plant diseases (Cross and Schlesinger, 1995; Magid et al., 1996; Griffith, 2010). Keeping in view the above facts, there is a great need to increase the productivity of chickpea to meet the nutritional requirement of the growing population. The present investigation was, therefore, undertaken to evaluate the influence of different Prates on productivity, resource-use efficiency and profitability of chickpea in Ghazni province Afghanistan.

MATERIALS AND METHODS

Experimental site

The present investigation was conducted at Research Farm of Agronomy Department, Agriculture Faculty of Ghazni University, during spring season of 2017. Geographically, the experimental field is located at 68° 28' 52" East longitude and 33° 31' 58" North latitude at an elevation of 2204 m above mean sea level.

Climate and soil

The Ghazni province is located in the southeast region of Afghanistan. Climate of the region is transitional between cold semi-arid and warm-summer humid continental climate. It has cold, snowy winters and warm dry summers. Precipitation is low and mostly occurs in winter. Soil of the experimental field was sandy clay loam in texture, low in organic matter and available P (1.0 mg kg^{-1}) having pH (8.5).

Experimental design and treatments

The experiment consisting of five P –rates, viz., 0, 15, 30, 45 and 60 kg P_2O_5 ha^{-1} was laid-out in a randomized complete block design, replicated four times. The whole amount of P was applied basally at the planting time. The P was applied through TSP the recommended dose of N (30 kg h^{-1}) was applied through urea. The half dose of N was given as basal and remaining half dose of N was top-dressed at 30 days after sowing. The local chickpea cultivar (*Waghaznakhud*) was used in this experiment.

Data collection

For root nodule count, five plants were selected randomly from sample row of each plot at maximum flowering stage. They were uprooted carefully with the help of *khurpa* (hoe) for counting the *Rhizobium* inhabited root nodules per plant. The roots of uprooted plants were washed carefully and nodules from the tap and lateral roots were counted and the average values were recorded as nodule number per plant. For yield estimation, the crop was harvested from the net-plot area and the pods were threshed manually. The weight of cleaned seeds was recorded as net-plot yield. The dried stover from each plot was harvested and weighed. Both seed and stover yields were expressed as t ha^{-1}. The gross returns were computed using prevalent market price of the chickpea grains (AFN 105 kg^{-1})

and straw (AFN 5 kg^{-1}) following standard procedure. The net returns were then calculated using respective cost of cultivation. For computing of benefit: cost ratio, the net return was divided with the cost of cultivation. The value so obtained was considered as cost benefit ratio.

The production efficiency (kg ha^{-1} day^{-1}) and monetary efficiency (AFN ha^{-1} day^{-1}) were computed using the following expressions (Kumar et al., 2015):

$$\text{Production efficincy (PE)} = \frac{(\text{Grain yield (kg ha}^{-1}))}{(\text{Crop duration})}$$

$$\text{Monetary efficiency (ME)} = \frac{(\text{Net returns (AFN ha}^{-1}))}{(\text{Crop duration})}$$

Regarding water-use efficiency (WUE); the seasonal water use (Et) was computed from profile water contribution (CS), effective rainfall (ER) and irrigation water applied (I) using following equation (Choudhary and Suri, 2014):

$$Et = CS + ER + I$$

The profile water contribution (CS) was not taken into consideration in current study. Thus, the effective rainfall and irrigational water use was considered as the seasonal total water use in the present study by taking into account the respective crop growth period by following the procedure as suggested by Choudhary et al. (2009). Water-use efficiency (WUE): The WUE was computed by using following formula (Choudhary et al., 2009):

$$\text{WUE (kg ha}^{-1}\text{ mm}^{-1}) = Y/E_t$$

Where, Y is the economic yield (grain yield in kg ha^{-1}) and TWU refers to total amount of seasonal water used in ha-mm, respectively.

The energy values for input (e.g. machinery, seeds, fertilizer, water, and labour requirements) and outputs (e.g. grain and stover) in different Prates were estimated based on the energy equivalents of the inputs and output (Table 1), the energy calculations like energy-use efficiency (EUE), energy productivity (EP) and net energy were calculated by using the following equation (Patil et al., 2014; Hatirli et al., 2008).

$$\text{Energy use efficiency} = \frac{(\text{Energy output (MJ ha}^{-1}))}{(\text{Energy input (MJ ha}^{-1}))}$$

$$\text{Energy productivity} = \frac{(\text{Chickpea grain yield (kg ha}^{-1}))}{(\text{Total energy input (MJ ha}^{-1}))}$$

Net energy benefit (MJ ha^{-1}) =

Total energy output (MJ ha^{-1}) – Total energy input (MJ ha^{-1}).

Table 1. Energy equivalents of inputs and outputs in agricultural production for the chickpea under varying phosphorus rates in Ghazni, Afghanistan

Particulars	Unit	Energy equivalent (MJ per unit)	Source
A. Inputs			
1. Human labor (man)	hr	1.96	(Mobtaker et al., 2012)
2. Machinery (tractor)	hr	62.7	(Nabavi-Pelesaraei et al., 2013)
3. Diesel fuel	Liter	56.31	(Barber, 2003)
4. Chemical fertilizers			
(a) Nitrogen (N)	kg	66.1	(Mousavi-Avval et al., 2011)
(b) Phosphate (P_2O_5)	kg	11.15	(Unakitan et al., 2010)
5. Water for irrigation	m^3	1.02	(Hamedani et al., 2011)
6. Seed (chickpea)	kg	25.0	(Thyagaraj, 2013)
B. Outputs			
1. Grain of chickpea	kg	25.0	(Thyagaraj, 2013)
2. Stover of chickpea	kg	10.0	(Thyagaraj, 2013)

Statistical analysis of data

The collected data was analysed statistically by using Fisher's 'analysis of variance techniques' and differences among treatment means were compared using least significant difference test at 5% probability level.

RESULTS AND DISCUSSION

Root nodule count and crop productivity

Data pertaining to *Rhizobium* inhabited root nodule count plant^{-1}at maximum flowering stage as influenced by different P rates is presented in Table 2. The results of the investigation showed the root nodule count plant^{-1}at maximum flowering stage was highest (27.4) when P_2O_5 was applied @ 60 kg ha^{-1} which was significantly higher over the treatments where P_2O_5 was applied @ 0, 15 and 30 kg ha^{-1}, but it was statistically at par with 45 kg P_2O_5 ha^{-1}. Dutta and Bandyopadhyay (2009) reported that in the presence of adequate supply of P, the bacterial cells became motile and flagellate which is the prerequisite for bacterial migration, but in P-deficient soils the infection remains latent leading to the poor nodulation. This might be the possible reason for better nodulation in P applied treatments. These findings are in line with those of Deepali et al. (2003) and Gulpadiya et al. (2014) who also reported enhancement in number of nodules with incremental levels of P.

Data regarding seed yield of chickpea as influenced by different rates of P have been presented in Table 2. The result revealed that seed yield of chickpea improved remarkably due to different P-rates. Application of P @ 60 kg P_2O_5 ha^{-1} resulted in the highest seed yield (2.04 t ha^{-1}) of chickpea. This treatment was significantly better over control, 15 and 30 kg P_2O_5 ha^{-1}, but was at par with 45 kg P_2O_5 ha^{-1}. The fertilization of increasing rates of P significantly increased the seed yield, due to the active biotic role of P in metabolic processes of plants and photosynthesis tended to increase at flowering, fruiting and grain formation which ultimately increased the yield attributes and subsequently the yield (Dass et al., 1997). Similar observations were also noted by Meena et al. (2010), Rathore et al. (2010) and Muhammad et al. (2012), who reported that there was a significant increase in seed yield of chickpea with P application, seed yield increased as P rate increased from 0 to 80 kg P_2O_5ha^{-1}. The highest level of P @ 60 kg P_2O_5 ha^{-1} produced highest straw yield (4.05 t ha^{-1}) of chickpea. This treatment was significantly superior to control, 15 and 30 kg P_2O_5 ha^{-1}, but it was statistically similar with 45 kg P_2O_5 ha^{-1}. This may be due to adequate supply of P_2O_5 that played a vital role in physiological and developmental processes in plant life and the favorable effect of these important nutrients might have accelerated the growth processes that in result increased straw yield of the crop.

Crop profitability

Cost of cultivation (Afn. ha^{-1}) of chickpea increased consistently due to phosphorus-application. Application of P_2O_5 influenced the cost of cultivation due to variable P_2O_5 application (Table 2). The maximum cost of cultivation was recorded with application of 60 kg P_2O_5 ha$^{–1}$ and minimum in control. In the current study, the maximum grass returns (2,33,941 Afn. ha^{-1}) was seen when $P_2O_5$was applied @ 60 kg ha^{-1} which was significantly higher over 0, 15 and 30 kg P_2O_5 ha$^{–1}$, but it was statistically at par with 40 kg ha$^{–1}$ (Table 2). Net returns data also reveals that the maximum net returns (184516 Afn. ha^{-1}) was obtained when P_2O_5 was applied @ 60 kg ha$^{–1}$ which was significantly higher than the treatments 0, 15 and 30 kg P_2O_5 ha$^{–1}$, but it was statistically at par with 45 kg P_2O_5 ha$^{–1}$ (Table 2). The higher gross and net returns were mainly due to higher grain and straw yields of chickpea in the respective application of P_2O_5. Benefit: cost ratio data reveals that the maximum benefit: cost ratio was obtained when P_2O_5 was applied @ 60 kg ha^{-1} which was significantly higher over 0 and 15 kg P_2O_5 ha^{-1}, and at par with 30 and 45 kg P_2O_5 ha^{-1}. The similar findings have also been reported by Kumar et al. (2017) who reported that application of 60 kg P_2O_5 ha^{-1} and 25 kg ha^{-1} sulphur recorded the highest net return and B:C ratio.

Resource-use efficiency

Data pertaining to irrigation water-use efficiency (IWUE), production efficiency and monetary efficiency as influenced by different P_2O_5 rates are presented in Table 3. During the study period the water-use was same in all the treatments. The significantly higher IWUE was registered with 60 kg P_2O_5 ha^{-1} than 0, 15 and 30 kg P_2O_5 ha^{-1}. But, the difference between 60 and 45 kg ha^{-1} P_2O_5 application was non-significant (Table 3). The higher IWUE at 60 kg ha^{-1} P_2O_5 application was mainly due to higher grain yield as amount of irrigation water used for each treatment was equal.

Production efficiency data revealed that maximum production efficiency (19.4 kg ha^{-1} day^{-1}) was seen when P_2O_5 was applied @ 60 kg ha^{-1} which was significantly higher over the treatments that included 0, 10 and 30 kg P_2O_5 ha^{-1}, but it was statistically at par with 45 kg P_2O_5 ha^{-1}. Monetary efficiency of chickpea under various rates of P application are given in Table 2. Results showed that application of 60 kg P_2O_5 ha^{-1} resulted in significantly higher monitory efficiency (1757 Afn. ha^{-1} day^{-1}) compared to 0, 15 and 30 kg P_2O_5 ha^{-1}. But the difference between 60 and 45 kg ha^{-1} P_2O_5 application was non-significant. Higher production efficiency (PE) and monetary efficiency in increasing rates of P was due to significantly higher grain yield, at increasing rates of P.

Energy relations of chickpea under different rates of P are given in (Table 4). Results indicate that less input energy was utilized for the control treatment than other treatments. With increasing P_2O_5 rates, input energy increased. High total energy output of 91,360 MJ ha^{-1} was produced by 60 kg P_2O_5 ha^{-1} and this was significantly superior over 0, 15 and 30 kg P_2O_5 ha^{-1}, but it was statistically at par with the 45 kg P_2O_5 ha^{-1}. The net energy output was significantly higher for the 60 kg ha^{-1} (79,810 MJ ha^{-1}) compared to 0, 15 and 30 kg P_2O_5 ha^{-1}. But the difference between 60 and 45 kg P_2O_5 ha^{-1} was non-significant. Again, 60 kg ha^{-1} P_2O_5 application showed significantly higher energy-use efficiency of 7.91 than control treatment and 15 kg ha^{-1} P_2O_5. But it was at par with the 30 and 45 kg P_2O_5 ha^{-1}. The trend in energy productivity was similar to the energy-use efficiency with 60 kg ha^{-1} P_2O_5 application recording significantly higher energy productivity (0.176 kg MJ^{-1}) compared to the control and 15 kg ha^{-1} P_2O_5 application.

CONCLUSION

Chickpea is a legume crop mostly grown in irrigated and also rainfed areas in some parts of Afghanistan. It is mostly consumed in the form of processed whole seed (boiled, roasted, parched, fried, steamed, sprouted, etc.). Phosphorus plays a key role in many of the physiological processes, such as the utilization of sugar and starch, photosynthesis, energy storage and transfer. Legumes generally have higher P requirement because the process of symbiotic nitrogen (N) fixation consumes a lot of energy. After going through the finding of the present study, it was concluded that the root nodules count, profitability, production efficiency and resource-use efficiency of chickpea consecutively improved with increasing P rates; and highest P rate of 60 kg P_2O_5 ha^{-1}resulted in maximum gross and net returns ha^{-1}. Therefore, it is suggested to farming community at Ghazni province that chickpea should be fertilized with 60 kg P_2O_5 ha^{-1} for higher yield, profit and resource-use efficiency.

Table 2. Effect of different P rates on number of nodules per plant, productivity and profitability of chickpea

P- rates (kg P_2O_5 ha^{-1})	Nodules $plant^{-1}$	Crop productivity		Crop profitability			
		Seed yield (t ha^{-1})	Straw yield (t ha^{-1})	Cost of cultivation (Afn. ha^{-1})	Gross return (Afn. ha^{-1})	Net return (Afn. ha^{-1})	B: C ratio
Control	14.8	1.66	3.31	44,225	1,90,365	1,46,140	3.30
15	18.1	1.73	3.57	45,525	1,99,775	1,54,250	3.39
30	24	1.83	3.64	46,825	2,10,449	1,63,624	3.49
45	25.4	1.99	3.85	48,125	2,28,520	1,80,395	3.75
60	27.1	2.04	4.05	49,425	2,33,941	1,84,516	3.84
SEm (±)	0.81	0.06	0.13	-	6,555	6,555	0.13
CD (P=0.05)	2.49	0.19	0.39	-	20,198	20,198	0.40

Table 3. Effect of different P rates on efficiency of water-use, production and monetary efficiency of chickpea

P- rates (kg P_2O_5 ha^{-1})	Water use (mm ha^{-1})	Water-use efficiency (kg ha^{-1} mm^{-1})	Production efficiency (kg ha^{-1} day^{-1})	Monetary efficiency (Afn. ha^{-1} day^{-1})
Control	225	7.36	15.4	1392
15	225	7.70	16.5	1469
30	225	8.14	17.4	1558
45	225	8.86	19.0	1718
60	225	9.05	19.4	1757
SEm (±)	-	0.27	0.58	62.4
CD (P=0.05)	-	0.83	1.78	192.3

Table 4. Effect of different P rates on total energy output, net energy benefit, energy-use efficiency and energy productivity of chickpea

P- rates (kg P_2O_5 ha^{-1})	Total energy input (MJ ha^{-1})	Total energy output (MJ ha^{-1})	Net energy benefit (MJ ha^{-1})	Energy-use efficiency	Energy productivity (kg MJ^{-1})
Control	10,881	74,528	63,647	6.85	0.152
15	11,048	79,001	67,953	7.15	0.157
30	11,216	82,139	70,924	7.32	0.163
45	11,383	88,362	76,979	7.76	0.175
60	11,550	91,360	79,810	7.91	0.176
SEm (±)	-	2,205	2,205	0.20	0.006
CD (P=0.05)	-	6,795	6,795	0.60	0.017

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