

Productivity and resource-use efficiency of greengram (*Vigna radiata*) as influenced by sowing methods and phosphorus levels under semi-arid conditions of Afghanistan

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ABSTRACT

A field experiment was conducted during the rainy season of 2015, at the Afghanistan National Agricultural Sciences and Technology University (ANASTU), Kandahar, to study the effect of sowing methods and phosphorus levels on greengram [*Vigna radiata* (L.) R. Wilczek]. The experiment was laid out in a split-plot design with 8 treatment combinations including 2 sowing methods (broadcast and line sowing) in main plots and 4 phosphorus levels (0, 30, 60 and 90 kg P₂O₅/ha) in subplots, replicated thrice. Significantly higher grain yield, biological yield, production efficiency and water-use efficiency were recorded under line sowing over broadcast method. The highest grain yield (1.42 t/ha), biological yield (4.56 t/ha), production efficiency (16.5 kg/ha/day) and water-use efficiency (8.0 kg/ha/mm) were obtained by applying 60 kg P₂O₅/ha. Significantly higher gross returns, net returns, benefit: cost ratio and monetary efficiency were also recorded under line sowing and at 60 kg P₂O₅/ha respectively. Line sowing at 45 cm × 5 cm spacing and 60 kg P₂O₅/ha were found better treatments for higher productivity, profitability and resource-use efficiency of greengram under semi-arid conditions of Afghanistan.

Key words: Greengram, Phosphorus levels, Productivity, Profitability, Resource-use efficiency, Sowing methods

Greengram is the most important crop after wheat, rice and maize in Afghanistan. It is grown both as summer and rainy crop, fitting well into existing cropping systems (Noorzai *et al.*, 2017). It plays an important role in the national economy and food security of Afghanistan. However, its yield is quite low in the country due to non-availability of high-yielding varieties and poor agronomic management practices. The efficient nutrient management especially phosphorus and line sowing of greengram may substantially enhance the yield even under traditional varieties and rainfed situations. Greengram is an energy-rich crop; so, phosphorus management plays a major role in

enhancing its productivity with healthy root system, which may lead to better nutrient and water acquisition in rainfed conditions besides promoting biological nitrogen fixation (Kumar *et al.*, 2016). The line sowing and phosphorus management may also enhance the efficiency of resources like sunlight, nutrients, water and space resulting in improved crop and water productivity, profitability and resource-use efficiency (Choudhary *et al.*, 2015). In the country, no systematic work has been done on suitability of sowing methods and optimum dose of phosphorus in green gram. Hence the present investigation was carried out to study the effect of sowing methods and phosphorus levels on productivity, profitability and resource-use efficiency of greengram under semi-arid conditions of Afghanistan.

A field experiment was conducted at the Afghanistan National Agricultural Science and Technology University, Kandahar, Afghanistan (31° 30' N; 65° 50' E; 1,010 m above sea-level) during the rainy season of 2015 (July to September). Kandahar is situated in southern Afghanistan, where climate is semi-arid to sub-tropical with extreme cold and hot situations. Average normal annual rainfall

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was 190.6 mm. On an average, there were 29 days per year with more than 0.1 mm precipitation. June was the driest month (no rainfall) while January was the wettest month (average rainfall 54 mm). The hottest month was July (mean temperature 31.9°C), whereas January was the coldest month (mean temperature 5.1°C). The average daily temperature variation was 16.7°C. The average monthly relative humidity ranged from 23% (June) to 59% (February).

The field experiment with 8 treatment combinations including 2 sowing methods (broadcast and line-sowing) in main plots and 4 phosphorus levels (0, 30, 60 and 90 kg P₂O₅/ha) in subplots was conducted in a split-plot design, replicated thrice. Experimental soil was sandy-clay loam in texture and almost neutral in reaction (pH 7.2). Using soil-test kit 'LaMotte Garden Guide Soil Test Kit (5679-01)' the soil was characterized as low in available nitrogen, medium in P₂O₅ and high in K₂O/ha. The statistical analysis was done by the standard procedures as suggested by Gomez and Gomez (1984). Critical difference (CD) values at $P = 0.05$ were used to determine the significant differences between treatment means.

Greengram variety 'NM 94' was sown on 1 July 2015 and fertilized with 30 kg N and 30 kg K₂O/ha with varying phosphorus levels (0, 30, 60 and 90 kg P₂O₅/ha), respectively, using urea, diammonium phosphate and potassium sulphate as basal application. Under line sowing, greengram seed was sown @ 25 kg/ha manually in rows at 45 cm distance at 5 cm depth. The gross plot size was 3.15 m × 4.0 m, whereas the net plot size was 1.8 m × 3.6 m under line-sowing and 2.65 m × 3.5 m under broadcast method. Pendimethalin (30 EC) was applied @ 1.0 kg a.i./ha in 750 litres water/ha as pre-emergence herbicide for weed control. Two hand weedings, first (30–35 days after sowing, DAS) and second (50–55 DAS) were also done. A total of 3 irrigations were given due to long dry spell during the whole crop growth along with 1 pre-sowing irrigation. First irrigation was given at 22 DAS while second and third irrigation at 43 DAS and 70 DAS, respectively.

Due to non-synchronous growth of greengram variety under study, the pods were harvested in 2 pickings (first pod-picking at 80 DAS, second pod-picking at 90 DAS). The pods were harvested and threshed manually. The grains obtained from each net plot were sun-dried for 4–5 days, weighed and converted into grain yield as kg/ha. The grain yield was recorded at 10% moisture content. The straw collected from net plot area was sun-dried properly and weighed as kg/ha. The gross returns were calculated using prevalent market price of the greengram grains (AFN 66.10/kg) and straw (AFN 4.72/kg) in the market using standard procedure. The net returns were then calcu-

lated using respective cost of cultivation. The production efficiency (PE) (kg/ha/day) and monetary efficiency (ME) (AFN/ha/day) were computed using the following expression (Kumar *et al.*, 2015):

Production efficiency (PE) = Total economic yield (kg/ha)/Duration of the crop

Monetary efficiency = Total net returns (AFN/ha)/Duration of the crop

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 (Et) in the present study by taking into account the respective crop-growth period by following the procedure:

Water-use efficiency (WUE) = Yield/Et

where, Y is the economic yield (grain yield, kg/ha) and Et refers to total amount of seasonal water used in ha-mm respectively.

Productivity and production efficiency of greengram were significantly affected by different treatments. Significantly higher grain yield, biological yield and production efficiency were recorded under line sowing as compared to broadcast method. Harvest index did not show any significant variation between line sowing and broadcast methods. Among the phosphorus levels, there was a consistent and significant increase in grain and biological yield and production efficiency of greengram up to 60 kg P₂O₅/ha with the highest grain yield, biological yield and production efficiency. Further increase in phosphorus level to 90 kg P₂O₅/ha led to a non-significant decline in grain and biological yield, while production efficiency showed a significant decline (Table 1). Harvest index was significantly influenced by different phosphorus levels. Yields increased only up to 30 kg P₂O₅/ha (Table 1). Interaction effect of sowing methods and phosphorus levels was found to be non-significant. This variation in grain and biological yield, harvest index and production efficiency due to methods of sowing may be attributed to better crop ecology and efficient use of resources (sunlight, space, water, nutrients and ambient CO₂ concentration) under line sowing over broadcast method (Choudhary and Suri, 2014; Pooniya *et al.*, 2015; Noorzai *et al.*, 2017). Increase in phosphorus levels right from 0 to 60 kg P₂O₅/ha also led to higher grain and biological yield and production efficiency which may be possible due to maximization of photosynthesis, respiration, energy storage and transfer, cell division and cell elongation with sufficient phosphorus nutrition which led to enhanced yield and production efficiency (Kumar *et al.*, 2015; Noorzai *et al.*, 2017). Decrease in grain and biological yield and production efficiency of greengram at 90 kg P₂O₅/ha as compared to 60 kg P₂O₅/ha may be attributed to the role of higher phos-

Table 1. Effect of sowing methods and phosphorus levels on productivity, production efficiency, water-use efficiency and economics of green gram

Treatment	Yield (t/ha)		Harvest index (%)	Production efficiency (kg/ha/day)	Water-use efficiency (kg/ha/mm)	Economics			Monetary efficiency (AFN/ha/day)
	Grain Yield	Biological yield				Cost of cultivation ($\times 10^3$ AFN/ha)	Net returns ($\times 10^3$ AFN/ha)	Benefit: cost ratio	
<i>Sowing methods</i>									
Broadcast sowing	1.18	3.97	29.6	13.6	6.6	20.5	70.8	3.44	813
Line sowing	1.28	4.23	30.0	14.8	7.1	20.5	78.2	3.81	899
SEm \pm	0.025	0.043	0.6	0.3	0.1	-	1.63	0.06	18
CD (P=0.05)	0.076	0.130	NS	0.9	0.4	-	4.95	0.19	56
<i>Phosphorus (kg P₂O₅/ha)</i>									
0	0.88	3.39	26.0	10.1	4.9	18.5	51.4	2.77	592
30	1.31	4.14	31.6	15.0	7.3	19.8	80.1	4.03	920
60	1.42	4.56	31.1	16.5	8.0	21.1	88.5	4.17	1,017
90	1.32	4.35	30.4	15.0	7.3	22.4	77.9	3.46	895
SEm \pm	0.036	0.060	0.8	0.4	0.2	-	2.30	0.08	26
CD (P=0.05)	0.108	0.183	2.4	1.2	0.6	-	7.00	0.24	80

phorus in inducing Fe and Zn deficiency in general which might have adversely affected the growth and development and finally yield attributes and yield of green gram.

During the crop-growth period, 3 irrigations (each of 60 mm) were applied to the crop with no rainfall received during the rainy season of 2015. Thus, the seasonal water use was 180 mm in the green gram crop under different treatments. Sowing methods showed significant differences for water-use efficiency with the highest value under line sowing. Among phosphorus levels, there was again a consistent and significant increase in WUE up to 60 kg P₂O₅/ha with the highest WUE under 60 kg P₂O₅/ha, thereafter, further increase in P application to 90 kg P₂O₅/ha led to a significant decline in WUE (Table 1). This may be due to adverse impact of excess phosphorus application on the growth and development of plant (Bairwa *et al.*, 2012). The WUE is dened as the crop yield/unit of crop water use and is the outcome of an entire suite of plant and environmental processes operating over the crop duration. Thus, WUE in green gram both under sowing methods and phosphorus levels followed the same trend as that of grain and biological yield (Table 1). The irrigation water used and precipitation did not differ among different treatments; however, ability of the plants under respective treatments to efficiently utilize the applied water and profile water due to better root-system might have led to significant variation in WUE in green gram in present investigation (Kumar *et al.*, 2016; Noorzai *et al.*, 2017).

Gross and net returns, benefit: cost ratio and monetary efficiency were also significantly influenced by different sowing methods and phosphorus levels. Significantly higher gross and net returns, benefit: cost ratio and monetary efficiency were recorded under line sowing over

broadcast method (Table 1). Line sowing exhibited crop yield and profitability which may be ascribed to better growth and development of green gram under line sowing as a result of efficient use of resources like sunlight, space, water, nutrients and ambient CO₂ concentration (Choudhary and Suri, 2014; Pooniya *et al.*, 2015; Rajpoot *et al.*, 2016a,b; Noorzai *et al.*, 2017). Gross and net returns, benefit: cost ratio and monetary-efficiency increased with the successive increase in phosphorus levels up to 60 kg P₂O₅/ha (Table 1). This may be owing to favourable effect of phosphorus application on the growth and development and yield of the crop (Kumar *et al.*, 2015, 2016).

It is inferred that line sowing of green gram at 45 cm \times 5 cm spacing and phosphorus application @ 60 kg P₂O₅/ha were found better treatments for higher yield, profitability, production efficiency, monetary efficiency and water-use efficiency. Line sowing and 60 kg P₂O₅/ha may be recommended to enhance productivity, profitability and resource-use efficiency of rainy season green gram under semi-arid conditions of Afghanistan.

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