

ISSN : 1812-5379 (Print)
ISSN : 1812-5417 (Online)
<http://ansijournals.com/ja>

JOURNAL OF AGRONOMY



ANSI*net*

Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Enhancing Water Use Efficiency, Nitrogen Fixation Capacity of Mash Bean and Soil Profile Nitrate Content with Phosphorous and Potassium Application

Safdar Ali, Asia Munir, Rifat Hayat and Shahzada Sohail Ijaz
Department of Soil Science, University of Arid Agriculture, Rawalpindi, Pakistan

Abstract: A field study was designed primarily, to observe the effect of phosphorous and potassium application in terms of improving water use efficiency and nitrogen fixation capacity of mash bean and secondly, on the nitrate content of soil. The experiment was carried out during summer 2003 on a silty loam soil (Typic Ustochrepts) at Research Farm of University of Arid Agriculture, Rawalpindi with phosphorous and potassium fertilization at recommended rates separately as well as in combination. The highest water use efficiency ($1.04 \text{ kg mm}^{-1} \text{ ha}^{-1}$, 8% above control) and total fixed nitrogen (57.24 kg ha^{-1} , 41.28% over control) was observed with treatment P + K fertilization at the rate of 80 and 40 kg ha^{-1} , respectively. $\text{NO}_3\text{-N}$ content of soil were significantly higher at 60-90 cm depth, highest (24.34 kg ha^{-1}) being with phosphorous application at the rate of 80 kg ha^{-1} .

Key words: Water use efficiency, WUE, legumes, phosphorous, potassium, soil nitrate, nitrogen fixation, mash bean

INTRODUCTION

Mash bean (*Vigna mungo* L.) holds a key position in the rainfed agriculture of northern Punjab. It is considered important due to its nitrogen fixation capacity and richness in protein content. Mash bean can fix atmospheric nitrogen up to $30\text{-}70 \text{ kg ha}^{-1}$ in one season^[1]. Therefore development and adoption of mash bean in set rotations with wheat can enhance the soil nitrogen fertility and cereal yields. The economic product of mash bean is seed grain, which is a good source of dietary protein (25-32%). Mash bean can be successfully grown on marginal lands where other crops perform poorly^[2].

Water use efficiency act as the indicator to check the ability of a crop to convert available water to economic yield. Increasing the efficiency of water use by crop continues to escalate as a topic of concern because of the increasing demand for water use and improved environmental quality by human population^[3]. Therefore, it is highly desirable to investigate the means to improve the water use efficiency of mash bean crop, especially in the rainfed agriculture. Phosphorous has been reported to improve water use efficiency in a number of crops. In low-P soils, the addition of phosphatic fertilizer increased the dry matter yield and WUE of pearl millet^[4]. The significance of potassium pertains to the increased number of pods per plant, number of grains per pod, straw yield, total dry matter production and grain yield of legume crops^[5]. Actually, the soil nutrient status affects

the growth efficiency of crops, which leads to improved dry matter production relative to given amount of water used by the crop. These changes increase the water using efficiency.

The soil enriching property of mash bean is of greater value especially to our country, where soils are deficient in organic matter, nitrogen and other soil fertility parameters^[6]. Being leguminous, mash bean meets most of its N requirements from N_2 fixation and has little dependence on soil or fertilizer N^[2]. In Swat, mash bean (black gram) has been reported to have fixed 47% of its N requirements from the air^[7]. Hence, it can contribute towards increased soil fertility. The efficiency of inoculation for better results is influenced by the proper availability of phosphorus and potassium. As these elements are directly involved in nutrition of legumes and help to improve the root as well as shoot growth of the crop. Phosphorus has a profound effect on normal functioning of N_2 fixing bacteria and also on number and weight of effective nodules on root system^[8]. Mahadhkar and Saraf have reported the positive role of phosphorus in increasing the yield of mash bean crop^[9]. Phosphorus fertilizer application alone did increase root weight but had negligible effect on number of nodules. However, when potassium applied the nodule numbers and size both were improved significantly^[10].

The objective of the study primarily was to observe the effect of phosphorous and potassium application on water use efficiency and nitrogen fixation capacity of mash bean and secondarily, on the nitrate content of soil.

MATERIALS AND METHODS

A field experiment was conducted on a silty loam soil (Typic Ustochrepts) at the Research Farm, University of Arid Agriculture Rawalpindi during summer 2003. The experiment was laid out in Randomized Complete Block Design with four replications. Treatment plot size was 5×4 m. The crop was sown with the help of single row hand drill with row spacing of 30 cm. The mash bean seed were inoculated with *Bradyrhizobium japonicum*. The treatments of the experiment were T₁: Control; T₂: P-fertilized (80 kg P₂O₅ ha⁻¹); T₃: K-fertilized (40 kg K₂O ha⁻¹); T₄: P-K fertilized (80 and 40 kg ha⁻¹).

Soil analysis: Physical and chemical properties of composite soil samples taken before sowing from the experimental field were determined, i.e., soil texture, pH, electrical conductivity, available phosphorus, NO₃-N, extractable potassium and organic matter (Table 1). The soil samples at planting and harvest were collected by using king tubes for nitrate nitrogen and soil moisture content from 0-30, 30-60 and 60-90 cm depths. The soil nitrate nitrogen was determined using method given by Vendrell and Zupancic^[11].

Assessment of N₂ fixation by xylem solute technique: Nitrogen fixation was estimated by the xylem solute

Table 1: Physico-chemical properties of experimental field

Characteristics	Value
Texture	Silt loam
Bulk density (mg m ⁻³)	
0-30 cm	1.0
30-60 cm	1.3
60-90 cm	1.4
Saturation (%)	35
Organic matter (%)	0.9
Soil pH	7.61
EC (dS m ⁻¹)	0.31
Moisture (%)	11.24
Nitrate nitrogen	
0-30 cm	8.25
30-60 cm	7.11
60-90 cm (µg g ⁻¹)	6.97
Available phosphorous (µg g ⁻¹)	5.7
Extractable potassium (µg g ⁻¹)	143

collected at the pod fill stage by vacuum extraction method, then concentrations of ureide, nitrate and amino N were determined by prescribed methods to calculate the relative abundance of ureide (RUN%) by the following formula:

$$\text{RUN\%} = \frac{4 \times \text{ureide} \times 100}{4\text{ureide} + \text{nitrate} + \text{amino-N}}$$

After getting the value of RUN %, the proportion of plant N derived from N fixation (Ndfa %) was estimated at the time of sampling the xylem sap.

Table 2: Rainfall and average temperature data during growing season (mm)

Dates	Rainfall (mm)				Average temperature (°C)			
	July	Aug	Sep	Oct	July	Aug	Sep	Oct
1	-	40.0	70	12.3		26.8	30.6	22.1
2	-	-	356	9.5	28.0	27.9	30.7	22.7
3	-	-	305	1.5	32.2	25.5	27.1	23.7
4	-	-	44	44	33.5	26.6	24.2	23.4
5	-	-	-	10.6	34.4	28.4	23.2	23.0
6	-	7.6	-	-	27.4	29.9	26.0	24.4
7	-	-	-	-	28.2	30.8	27.5	25.4
8	-	11.4	27.7	8.2	29.1	26.2	26.9	22.2
9	22.3	-	3.5	-	26.4	26.4	25.7	21.4
10	22.5	40.2	-	5.2	27.3	27.7	27.6	21.8
11	-	1.2	-	-	27.9	29.0	27.6	20.5
12	-	-	-	-	27.8	29.6	28.0	20.5
13	-	20.6	-	-	26.2	28.4	29.6	21.3
14	-	17.2	-	-	29.2	29.4	29.1	22.1
15	-	-	-	-	30.7	29.6	21.1	22.4
16	-	-	-	-	26.6	30.4	28.4	210.7
17	-	9.0	-	-	28.2	20.6	28.6	22.0
18	4.6	-	-	-	29.7	31.1	29.4	22.3
19	-	-	3.5	1.8	31.2	25.8	29.3	21.8
20	-	-	57	-	32.3	24.3	30.4	22.0
21	36.2	-	26.6	-	26.4	26.6	30.5	21.7
22	36.5	94.2	-	-	28.7	28.2	30.2	21.4
23	-	-	-	-	30.3	29.0	29.8	20.4
24	-	-	-	-	28.9	30.0	22.1	21.3
25	-	3.0	-	48	28.0	39.9	20.3	21.5
26	-	-	-	66.5	30.2	29.5	23.8	20.3
27	23.0	4.2	-	-	20.1	28.8	24.6	21.5
28	8.0	14.0	-	-	27.1	29.1	20.0	20.6
29	-	25.5	-	66.5	27.9	29.0	22.7	21.7
30	-	7.6	12.3	-	27.5	27.9	22.9	21.2
31	-	16.7	12.5	-	29.8	29.1	22.5	21.3

Total rainfall during the growing period: 1383.6 mm

The legume N was derived from the measure of biomass accumulation and tissue N-content.

$$\text{Legume N (kg ha}^{-1}\text{)} = \text{Legume biomass (kg ha}^{-1}\text{)} \times \text{N\%}$$

The amount of nitrogen fixed by legume was regulated by two factors, the amount of N accumulated during growth and the production of that N derived from symbiotic N_2 fixation Ndfa%).

$$\text{Amount N}_2 \text{ fixed (kg ha}^{-1}\text{)} = \text{Ndfa\%} \times \text{Crop N (kg ha}^{-1}\text{)} \times 1.5^*$$

*1.5 factor is used to include an estimate for contribution by below ground N.

Water use efficiency of grain yield: Water use efficiency of grain yield were calculated by combining grain yield with data on water use^[13]

$$\text{WUE} = e/(f - g + h)$$

Where, e is grain yield (kg ha^{-1}), f and g are soil water contents (mm) to 120 cm depth measured at planting and at harvest, respectively. h is growing season precipitation.

Meteorological data: Rainfall data and average temperature data (Table 2) necessary for interpreting the results was obtained from Regional Agro-met Center located at University Farm.

Statistical analysis: The data collected for various characteristics were analyzed statistically by analysis of variance technique and the means obtained were compared by LSD at 5% level of significance^[14].

RESULTS AND DISCUSSION

Effect of phosphorous and potassium on percent nitrogen derived from atmosphere (Ndfa%): The impact of phosphorous and potassium on the proportion of nitrogen derived by mash bean through the N_2 fixation (Ndfa%) at pod fill stage (Table 3) reveals that the average Ndfa% values observed were 24, 35, 28 and 44% with T_1 , T_2 , T_3 and T_4 treatments, respectively. The results were statistically significant. The highest value was obtained with the combined use of phosphorous and potassium i.e., 44% (46% over control) followed by T_2 , T_3 and T_1 . The higher values for Ndfa% obtained with phosphorous and in combination with potassium indicates that mainly phosphorous enhanced nitrogen fixation and potassium stimulated it. The results were in conformity with those given by Shehzadi *et al.*^[15] who suggested that phosphorous application enhanced Ndfa%.

Table 3: Effect of phosphorous and potassium on % Ndfa, Total N fixed, WUE and grain yield of mash bean

Treatments	Ndfa%	Total N fixed (kg ha^{-1})	Grain yield (t ha^{-1})	WUE ($\text{kg mm}^{-1} \text{ha}^{-1}$)
T_1	24d*	35b	1.26b	0.90c
T_2	35b	36b	1.37ab	0.97b
T_3	28c	33b	1.40ab	0.96bc
T_4	44a	57a	1.47a	1.04a

*Means with different letter (s) differ significantly according to LSD ($p = 0.05$)

Effect of phosphorous and potassium on total N fixed (kg ha^{-1}) by mash bean: In Table 3 total fixed N_2 obtained were 35, 36, 33 and 57 kg ha^{-1} for T_1 , T_2 , T_3 and T_4 , respectively. The maximum amount of fixed N_2 was obtained for treatment where phosphorus and potassium were combined and was significantly higher than that for control and P or K alone treatments. The P or K alone treatments did not produce significantly higher N_2 fixed than the control treatment.

The reason for greater amount of total fixed nitrogen in T_4 was that the availability of phosphorus along with potassium probably enhanced the microbial activity and in return increased amount of nitrogen fixed by mash bean. The similar findings have been reported by Khan *et al.*^[16] on N_2 fixation in *Sesbania aculeate*.

Effect of phosphorous and potassium on water use efficiency of mash bean: Table 3 presents significantly higher water use efficiency of mash bean with combined application of phosphorous and potassium. Maximum value of water use efficiency i.e., $1.04 \text{ kg mm}^{-1} \text{ha}^{-1}$ (8% above control) was obtained in T_4 (P + K at the rate of 80 kg ha^{-1} and 40 kg ha^{-1}) followed by T_2 (P at the rate of 80 kg ha^{-1}). The lowest value, $0.90 \text{ kg mm}^{-1} \text{ha}^{-1}$, was obtained in T_1 (Control). The findings are in line with the observations of Payne *et al.*^[4] who reported that the addition of phosphorous increased the dry matter yield and water use efficiency of pearl millet.

Effect of phosphorous and potassium on grain yield of mash bean: The grain yield was 1.26, 1.37, 1.40 and 1.47 t ha^{-1} under T_1 , T_2 , T_3 and T_4 treatments, respectively (Table 3). When the treatments were compared with each other it was revealed that the highest grain yield (1.47 t ha^{-1}) was obtained by T_4 while T_1 produced the lowest grain yield of 1.26 t ha^{-1} . The results were statistically significant. The increase in yield may be attributed to adequate supply of phosphorous by improving seed development as it is essential for seed formation and potassium stimulated it. The percent increment over control observed was 8.03, 10 and 14.3% for T_2 , T_3 and T_4 , respectively.

The results were in agreement with Sharar *et al.*^[17] who reported that improved grain yield of legumes by phosphorous application.

Table 4: Effect of phosphorous and potassium on residual soil nitrate content at different depths

Treatments	0-30 cm depth	30-60 cm depth	60-90 cm depth
T ₁	24.2a*	20.8a	16.37b
T ₂	23.5a	23.0a	24.34a
T ₃	24.0a	20.3a	16.09b
T ₄	24.3a	22.0a	19.66ab

*Means with different letter (s) differ significantly according to LSD (p = 0.05)

Effect of phosphorous and potassium on residual soil nitrate content: Mash bean being a nitrogen fixer, has effect on soil nitrate nitrogen content. After harvesting the crop, the NO₃-N contents were found to be 24.2, 23.5, 24 and 24.3 kg ha⁻¹ under T₁, T₂, T₃ and T₄, respectively. The data indicated the non-significantly difference among the treatments at 0-30 cm depth. However, the highest soil NO₃-N contents (24.3 kg ha⁻¹) were observed with P+K fertilized at the rate of 80 kg and 40 kg ha⁻¹ treatment and the lowest nitrate nitrogen (24 kg ha⁻¹) was found in T₃ where only potassium was applied at the rate of 40 kg ha⁻¹ (Table 4).

At 30-60 cm depth, the soil NO₃-N contents were 20.8, 23, 20.3 and 22 kg ha⁻¹ with treatment under T₁, T₂, T₃ and T₄, respectively. The differences were statistically non significant. However, maximum amount was observed in T₂ where only phosphorus was applied at the rate of 80 kg ha⁻¹.

At 60-90 cm depth, the soil NO₃-N contents after mash bean harvest were 16.37, 24.34, 16.09 and 19.66 kg ha⁻¹ under treatments T₁, T₂, T₃ and T₄, respectively. Results obtained were statistically significant at this depth. The highest nitrate content of 24.34 kg ha⁻¹ was observed in P fertilized treatment and the lowest contents (16 kg ha⁻¹) were observed in K fertilized treatment (Table 4).

The higher nitrate content at lower soil depths (60-90 cm) may be result of leaching of nitrate to lower depths with rain water. The results also indicated that effect of mash bean on NO₃-N content of soil was better by using phosphorous only. This suggests that phosphorous is beneficial for increasing NO₃-N at different soil depths. The results were in conformity with those of Nimje and Seth who reported that phosphorous application improves total nitrogen content of soil. High plant densities will more rapidly deplete soil nitrate and favour earlier establishment of a functioning symbiosis^[18].

ACKNOWLEDGMENTS

Financial support from the Pakistan Science Foundation is gratefully acknowledged.

REFERENCES

1. Yamada, N., 1974. Biological nitrogen fixation limitless resources supporting agriculture (In Ja). Netti NokenShuho, 25: 20-28.
2. Ghafoor, A., Z. Ahmad and A. Qayyum, 2003. Black gram (*Vigna mungo* L. Hepper). Germplasm Catalogue. Plant Genetic Resources Prog. PARC/JICA, Islamabad, Pakistan, pp: 75-80.
3. Hatfield, J.L., T.J. Sauer and J.H. Prueger, 2001. Managing soils to achieve greater water use efficiency: A review. Agron. J., 93: 271-280.
4. Payne, W.A., L.R. Hossner, A.B. Onken and C.W. Wendt, 1995. Nitrogen and phosphorous uptake in pearl millet and its relation to nutrient and transportation efficiency. Agron. J., 87: 425-431.
5. Mushtaq, M., P. Shah, S. Jan and A. Sattar, 1986. Effect of different levels of phosphorous and potash on the emergence of plant height and straw yield of mung bean. Sarhad J. Agric., 2: 467-469.
6. Ofori, F. and W.R. Stern, 1987. Cereal-legume intercropping systems. Adv. Agron., 41: 41-90.
7. Shah, Z., S.H. Shah, M.B. Peoples and D.F. Herridge, 1997. Survey of N₂ fixation of lentil, mungbean and black gram in farmers' fields in North West Frontier Province, Pakistan. Extending Nitrogen Fixation Research to Farmers' Fields. Proceeding of an International Workshop on Managing Legume Nitrogen Fixation in the Cropping Systems of Asia, 20-240. Aug. 1996. ICRISAT, India, pp: 333-343
8. Taiwo, L.B., F.C. Nworgu and O.B. Adatayo, 1999. Effect of *Rhizobium japonicum* inoculation and phosphorous fertilization on growth, nitrogen fixation and yield of promiscuously nodulation in soybean (*Glycine max* L. Merrill) in a tropical soil. Crop Res. Hisar., 18: 169-177.
9. Mahadkar, U.V. and C.S. Saraf, 1991. Nutritional status and grain yield of spring and bean as influenced by *Rhizobium* inoculation, nitrogen and phosphorous application. J. Maharashtra Agric. Univ., 16: 321-323.
10. Shaukat, A., 1994. Effect of nitrogen and phosphorous fertilizers on root growth and nodulation in black locust (*Robinia pseudoacacia* L.) seedlings. Pak. J. For., 44: 65-72.
11. Vendrell, P.F. and J. Zupancic, 1990. Determination of soil nitrate by transnitration of salysylic acid. Comm. Soil Sci. Plant Anal., 21: 1705-1713.
12. Peoples, M.B., A.W. Faizah, B. Rerkasam and D.F. Herridge, 1989. Methods for evaluating nitrogen fixation by nodulated legumes in the field. Monograph No. 11. Canberra, Aust Center Int. Agric. Res.

13. Gregory, P.J., 1991. Concept of Water Use Efficiency. Soil and Crop Management for Improved Water Use Efficiency in Rainfed Areas, Harris, H.C., P.J. Harris, M. Cooper and M. Pala, Eds., ICARDA, pp: 9-20.
14. Steel, R.G.D. and J.H. Torrie, 1980. Principles and Procedures of Statistics. 2nd Edn., McGraw Hill Book Company Inc., New York, pp: 188-189.
15. Shehzadi, S., S. Ali and S.S. Ijaz, 2003. Role of phosphorous and inoculation in nitrogen fixation by soybean selection NARC-6. Pak. J. Soil. Sci., 22: 87-91.
16. Khan, H.R., M.M.A. Buiyan, F. Azim and M.K. Rehman, 2001. Effect of phosphorous and potassium on biomass production, nodulation and nutrient content in *Sesbania aculeate*. Curr. Agric., 25: 55-60.
17. Sharar, M.S., M. Ayub, M.A. Chaudhry, A.A. Rana and M.M.Z. Amin, 1999. Growth and yield response of two cultivars of mung bean to various levels of phosphorous. Pak. J. Biol. Sci., 2: 1385-1386.
18. Nimje, P.M. and J. Seth, 1986. Effect of phosphorous, farmyard manure and nitrogen on soil properties in a soybean maize sequence. J. Agric. Sci. Camb., 107: 555-559.