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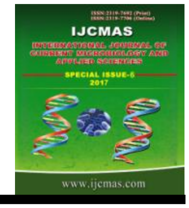

Original Research Article

Response of Split Application of Nutrients through Fertigation on Nutrients Uptake, Nutrient and Water Use Efficiency and Yield of Pigeon pea

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Drip, Pigeon pea, Fertigation, NPK, Uptake, WUE, NUE

ABSTRACT

A field investigation entitled "Response of pigeon pea to different drip fertigation levels" was carried out at Department of Agronomy Farm, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during the *kharif* season of 2016-17. The experiment was laid out in Randomised Block Design with four replications and eight different irrigation and fertigation treatments imposed for pigeon pea crop with an objective to study the response of split application of N, P and K on nutrients uptake, water and nutrient use efficiency and yield of Pigeon pea. The experimental site was established with inline drip irrigation system (16 mm) lateral laid out at 90 cm with 30 cm dripper spacing. Irrigation water was applied through drip irrigation system on every alternate day at the rate of 100 per cent crop evapotranspiration level. Experiment results revealed that, in pigeon pea, the nutrients uptake was favourably increased with higher level of fertigation compared with lower levels and soil application method. At all the stages of crop growth, higher uptake of N, P and K were observed at 125:100:100 per cent levels of N, P and K fertigation. Progressive increase in applied level of N, P and K correspondingly increased the nutrient uptake and lower uptake was noticed in conventional method of fertilizer application in furrow irrigation. Water use efficiency was markedly improved by drip fertigation at higher level compared to conventional soil application. However, NUE showed a declining trend with increasing level of N, P and K, but higher NUE in drip fertigation was observed than conventional method of fertilizer application. As a consequence of better nutrient uptake and WUE, drip fertigation at 125:100:100 per cent recommended dose of NPK ha^{-1} had recorded higher pigeon-pea seed yield of 3866 kg ha^{-1}. It could be concluded that application of 125:100:100 per cent recommended dose of N, P and K in five splits found to be best for better uptake of nutrients, WUE and maximizing the pigeon pea yield through fertigation.

Introduction

Pigeon pea is a pulse crop belongs to the family leguminoceae (Fabaceae) and it is a multipurpose legume with a long tradition of cultivation over three thousand years. It is the most widely grown crop in the country in tropic and sub tropics region and has been considered as a second most important pulse crop after chickpea. India has virtual monopoly in pigeon pea production accounting to 90% of world's total production. In India alone, pigeon pea are grown in about 3.90million hectares, with a production of 3.17 million ton, however the average productivity is only 813kgha^{-1}.

More than 85% area of pigeon pea is under rainfed condition. The demand for pulses is increasing due to increasing population. To meet the demand pigeon pea productivity has to be increased. Improper irrigation and nutrient management are the main reason of low productivity of pigeon pea in Maharashtra.

Increasing demand for irrigation water coupled with depleting ground water sources calls for efficient use of water. Therefore, there is need for efficient irrigation methods to these crops. The present scenario of flood irrigation should give away to controlled irrigation, such as drip irrigation which offers enormous use for economy of irrigation water and fertilizer chemicals. In conventional method, there is a heavy loss of nutrients due to leaching, denitrification, evaporation and fixation in the soil. Drip irrigation and fertigation are technologies which improve both water and fertilizer use efficiency to a great extent. Fertigation gives flexibility of fertilizer application, which enables the specific nutritional requirement of the crop to be met at different stages of its growth. Split application of fertilizers ensures required nutrients in right time and in right quantity for getting higher yield with minimum loss of nutrients. Nitrogen, phosphorus and potassium fertilizers are water soluble and play a major role in the growth and development of pigeon pea crops. In general, injection of fertilizers into irrigation water gives a better crop response than either band or broadcasting. Drip irrigation and fertigation will help to increase area under pigeon pea cultivation under water scarcity condition which will help to increase the branches/plant, nodule/plant, pods/plant which will ultimately increases the yield. In this respect fertigation proposed as a means to increase efficient use of water and fertilizer to increase yield, protect environment and sustained irrigated agriculture. Hence, the present study was initiated to study the response of split application of nutrients on NPK uptake, water and nutrient use efficiency and yield of pigeon pea under drip fertigation.

Materials and Methods

The field experiment was carried out at Agronomy Farm, Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during the *kharif* seasons of 2016-17. The topography of the field was fairly uniform and level. The soil was medium black cotton belonging to Vertisols. The experiment was laid out in randomised block design with four replications and eight different fertigation treatments imposed for pigeon pea crop i.e. 100 per cent RDNPK through soil application with furrow irrigation (T_1), drip irrigation with 100 per cent RDNPK through soil application (T_2), drip fertigation with 125:75:75 per cent RDNPK in five splits (T_3), drip fertigation with 100:75:75 per cent RDNPK in five splits (T_4), drip fertigation with 75 per cent RDNPK in five splits (T_5), drip fertigation with125:100:100 per cent RDNPK in five splits (T_6), drip fertigation with 100 per cent RDNPK in five splits (T_7), drip fertigation with 75:100:100 per cent RDNPK in five splits (T_8). The experiment site was established with inline drip irrigation system (16 mm) lateral laid out at 90 cm with 30 cm dripper spacing. Irrigation water was applied through drip irrigation system on every alternate day at the rate of 100 per cent crop evapotranspiration level.

The sources of nutrients were urea (46% N), single super phosphate (16% P_2O_5), phosphoric acid and murate of potash (60% K_2O) for nitrogen, phosphorus and potash, respectively. The fertilizer was applied as per the treatments. Full dose of the nitrogen, phosphorus (through SSP) and potassium were applied to the treatments T_1 and T_2 through soil application at the time of sowing by the conventional method. Remaining treatments (T_2, T_3, T_4, T_5, T_6, T_7 and T_8) were applied with N, P (through phosphoric acid) and K in fertigation treatments in five unequal splits as per the growth stages of pigeon pea. The fertilizer tank of 90 litre capacity was used to apply chemical fertilizer through the irrigation water. The variety of Pigeon pea PKV-TARA was sown on 11th June 2016 with recommended dose of fertilizers 25:50:30 kg NPK ha^{-1}.

Results and Discussion

Nutrients uptake

The data presented in Table 1 revealed that significant difference in N, P and K uptake of pigeon pea was observed under various treatments. The total N, P and K uptake at harvest include the uptake by plant and seed as shown in Table 1.

Nitrogen uptake

In the present investigation, it was observed that nitrogen uptake in pigeon pea plant was more in grain than stalk. Successive increase in fertigation levels from 75 per cent to 125:100:100 per cent RDNPK resulted significant increase in total nitrogen uptake over its preceding lower level. Drip fertigation with 125:100:100 per cent RDNPK in five splits found significantly higher total nitrogen uptake compare to lower level of fertigation and conventional method of fertilizer application but found at par with drip fertigation with 100 per cent recommended dose of N, P and K in five splits and drip fertigation with 75:100:100 per cent recommended dose of N, P and K in five splits. Drip fertigation with 75 per cent RDNPK and drip irrigation with 100 per cent RDNPK through soil application found at par with each other. The concentration and availability of various nutrients in the soil for plant uptake depends on soil solution phase which is mainly determined by soil moisture availability. The higher available soil moisture provided due to continuous water supply at alternate days under drip Irrigation led to higher availability of nutrients in the soil and thereby increased the nutrient uptake under drip fertigation levels in splits was the result of increased biomass production due to continuous availability of water and nutrients to the crop.

An application of N given through fertigation not only stimulated vegetative growth and foraging capacity of roots, but also encouraged the absorption and growth and translocation of more nutrients under higher drip fertigation levels. Due to improved growth characters, the plants tend to take more nutrients from the soil since it was available nearer to root zone at required level. Reducing the fertilizer resulted in reduced availability of nutrients which might be the reason for lower uptake of nutrients by crop at lower doses of fertilizers as indicated in the present study. In conventional method of soil application of fertilizers, application of large quantity of fertilizers as a single dose resulted in higher volatilization losses of nutrients and resulted in lower availability of nutrients during later growth stages of crop. This might be the reason for lower uptake of nutrients by crop, when fertilizers are applied by conventional method. Further application of nutrients in more number of splits through drip irrigation resulted in minimum or no wastage of nutrients either through deep percolation or volatilization ultimately led to higher uptake as reported by Raskar (2004). Hassan *et al.,* (2010) revealed that maximum N uptake

(120.4 kg ha^{-1}) was observed with the application of 140 kg N $ha.^{-1}$ through drip fertigation in maize. Higher nutrient uptake with higher level of fertigation over soil application was also reported by Goud and Kale (2010), Bhalerao *et al.,* (2011), Ayyadurai *et al.,* (2014), Praharaj *et al.,* (2014), Vimalendran and Latha (2016).

Phosphorus uptake

As indicated in Table1, different fertigation levels and soil application method showed significant influence on total phosphorus uptake by plant. As in case of nitrogen, drip fertigation with 125:100:100 per cent RDNPK in five splits found significantly higher nutrient uptake compare to conventional method and lower level of fertigation. Drip fertigation with 75 per cent RDNPK found at par with drip irrigation with 100 per cent recommended dose of N, P and K through soil application. The lowest P uptake was recorded at 100 per cent RDNPK in furrow irrigation and soil applied treatment. Raskar (2004) reported that the application of fertilizers in soil application and either 50 or 75 per cent recommended dose of fertilizer through drip registered lower nutrient uptake by the crop. The increased nutrient uptake might be due to adequate and sustained availability of nutrients throughout the growth stages of crop and mineralization of nitrogen and slow release of fixed P to pigeon pea. Avnish Kumar and Kushwaha (2006) reported that phosphorus uptake in pigeon pea increased with increase in phosphorus application up to 8O kg ha^{-1}.

The significant increase in P uptake in pigeon pea plant and total uptake with increase in fertigation level might be related to increase in dry matter accumulation and P content in plant with increase in fertigation levels. Increasing the soil nutrient availability with drip fertigation at higher level as compared to conventional soil application was reported by Shankarlingappa *et al.,* (2000), Praharaj and Kumar (2012), Ayyadurai *et al.,* (2014), Praharaj *et al.,* (2014), Vimalendran and Latha (2016).

Potassium uptake (kg ha^{-1})

In the present Investigation it was observed that potassium uptake in pigeon pea plant was more in stalk than grain at harvest. Different fertigation levels and soil application of fertilizer in furrow and drip method showed significant influence on potassium uptake by plant similarly to nitrogen and phosphorus uptake. Successive increase in fertigation levels from 75 per cent to 125:100:100 per cent RDNPK ha^{-1} resulted significant increase in potassium uptake over its preceding lower level. Drip fertigation with 125:100:100 per cent RDNPK in five splits found significantly higher K uptake compare to conventional method of fertilizer application and lower level of fertigation but found at par with drip fertigation with 100 per cent recommended dose of N, P and K in five splits and drip fertigation with 75:100:100 per cent recommended dose of N, P and K in five splits. Fertigation with water soluble K fertilizers like MOP allows easy application of nutrients in splits to the rhizosphere so as to match the physiological needs of the crop for better root development and fruit development stages. Application of higher and optimum dose of fertilizers through fertigation resulted in maximum uptake of nutrients at all the stages, which indicates that increasing the dose, increased the availability which in turn resulted in higher uptake by plants. Similar results were also reported by Shankarlingappa *et al.,* (2000), Goud and Kale (2010), Raskar (2004) and Praharaj *et al.,* (2014) in respect of more K uptake due to higher level of fertigation over soil application by conventional method and over lower level of fertigation.

Water use efficiency (kg ha^{-1} mm^{-1})

The data on water use efficiency of pigeon pea under drip fertigation as influenced by different treatments are presented in Table 2. In the present investigation, there was a positive relation among increasing drip fertigation level and seed yield. The highest WUE of 6.04 kg ha^{-1} mm^{-1} was registered under drip fertigation with 125:100:100 per cent recommended dose of N, P and K in five splits compare to other fertigation treatments. Furrow irrigation with 100 per cent recommended dose of N, P and K recorded lower WUE of 2.35 kg ha^{-1} mm^{-1} because of lower seed yield and more water use in this treatment. Nitrogen, Phosphoric acid and potassium applied through drip irrigation had distinct bearing as evident from higher WUE with higher level of RDNPK. Markedly higher WUE with higher level of fertigation than lower level, because of adequate and timely availability of water and nutrient and their positive interaction might have simulated the early growth and increased the yield to record higher WUE under drip fertigation with higher level compared to soil application of fertilizers. Sudhakar and Rao (1996), Gajera and Ahlawat (2006), and Praharaj *et al.,* (2017) also reported the similar finding of increasing WUE with increasing level of fertigation.

Nutrient use efficiency (kg ha^{-1})

Nutrient use efficiency is a measure of utilization of applied nutrients for crop growth and seed yield (economic yield). In the present study, different drip fertigation levels showed distinct variation in nutrient use efficiency (Table 2). Increasing the level of N, P and K application by drip fertigation reduced the NUE. Drip fertigation with 75:100:100 per cent RDNPK in five splits has recorded a higher NUE of 36.01 kg seed yield kg^{-1} nutrient applied as against 16.45 kg seed yield kg^{-1} nutrient applied in furrow irrigation with 100 per cent RDNPK through soil application. In spite of higher nutrient uptake at higher fertigation doses, 125:100:100 per cent RDNPK fertigation has resulted in lower NUE. The trend of increasing NUE is inversely proportional to the fertigation doses as earlier reported by Malakouti (2004).

The conventional method of soil application of fertilizers at 100 per cent RDNPK ha^{-1} has resulted lower NUE of 16.45 kg kg^{-1} seed yield than all the fertigation treatments which clearly indicates the superiority of drip fertigation over conventional soil application of N, P and K fertilizers. The study clearly brought out 25 per cent increased NUE at 75 per cent RDNPK through fertigation in five splits as compared to soil application at 100 per cent RDNPK in furrow, revealing possibility of 25 per cent saving of fertilizers by drip fertigation.

The nutrient use efficiency was considerably increased in drip fertigation compared to soil application of N, P and K fertilizers. This could be attributed to regular application of N,P and K (as high as five splits in drip fertigation) combined with irrigation water in the active root zone of the crop and their interaction in even N distribution in the soil with minimum leaching of nutrients away from the root zone. These results are in accordance with the findings of Escobar (1995), Hassan *et al.,* (2010) and Veeraputhiran (2000). In the conventional application of fertilizer the decrease in nutrient use efficiency with increase in fertilizer level might be the result of increase in yield but at decreasing rate.

Table.1 Influence of different fertigation treatments on NPK uptake (Kgha^{-1}) of pigeon pea

Treatments	N Uptake (Kgha^{-1})			P Uptake (Kgha^{-1})			K Uptake (Kgha^{-1})		
	Grain	Stalk	Total N	Grain	Stalk	Total P	Grain	Stalk	Total K
T_1 :FI with 100 % RDF Soil application	66.14	63.35	129.50	7.79	7.15	14.94	23.13	61.88	85.01
T_2:DI with 100 % RDF Soil application	80.02	70.58	150.61	9.49	7.85	17.35	24.21	67.36	91.57
T_3 :DF with 125% N + 75% P+75% K in five splits	90.39	73.41	163.80	11.42	8.46	19.88	27.14	72.10	99.24
T_4:DF with 100% N + 75% P+75% K in five splits	86.03	73.50	159.58	11.84	8.34	20.18	27.10	72.80	99.90
T_5:DF with 75% N + 75% P+75% K in five splits	84.62	72.13	156.75	10.17	8.22	18.39	26.10	71.60	97.70
T_6 :DF with 125% N + 100% P+ 100% K in five splits	98.44	80.85	179.29	14.50	11.80	26.30	30.06	76.04	106.10
T_7:DF with 100% N + 100% P+ 100% K in five splits	93.72	77.46	171.18	13.50	10.43	23.93	29.25	75.43	104.68
T_8:DF with 75% N + 100% P+ 100% K in five splits	91.65	76.64	168.29	12.90	10.05	22.95	28.23	74.6	102.83
S.E.m$\pm$	2.15	2.15	3.74	0.44	0.27	0.64	0.61	1.46	1.95
CD at 5%	6.34	6.33	11.00	1.31	0.79	1.89	1.78	4.28	5.74

FI: Furrow Irrigation DI: Drip Irrigation DF: Drip Fertigation

Table.2 Water use efficiency, nutrient use efficiency and yield of pigeon pea as influenced by different fertigation treatments

Treatments	WUE (ha^{-1}mm^{-1})	NUE (kg kg^{-1})	Grain yield (kg/ha)
T_1 :FI with 100 % RDF Soil application	2.35	16.45	1727
T_2:DI with 100 % RDF Soil application	4.07	24.83	2607
T_3 :DF with 125% N + 75% P+75% K in five splits	5.02	35.22	3214
T_4:DF with 100% N + 75% P+75% K in five splits	4.78	36.01	3060
T_5:DF with 75% N + 75% P+75% K in five splits	4.38	35.61	2804
T_6 :DF with 125% N + 100% P+ 100% K in five splits	6.04	34.75	3866
T_7:DF with 100% N + 100% P+ 100% K in five splits	5.78	35.28	3704
T_8:DF with 75% N + 100% P+ 100% K in five splits	5.47	35.50	3506
S.E.m$\pm$	--	--	147
CD at 5%	--	--	432

Effect on pigeon pea yield

Maximum pigeon pea grain yield (3866 $Kgha^{-1}$) was recorded where 125% N + 100% P+ 100% K was applied in five splits through drip irrigation and was found significantly superior over all other treatments except treatment drip fertigation with 100% N + 100% P+ 100% K in five splits (3704 Kg) and drip fertigation with 75% N + 100% P+ 100% K in five splits (3506 Kg) which was found at par with each other in respect of grain yield.

Differences between treatment 100 % RDF through soil application and DF with 75% N + 75% P+75% K in five splits treatments were not significant but both the treatments were significantly superior to 100 per cent dose of N, P and K given in furrow irrigation. There was 55.32% increase in yield in treatment where higher level of fertigation (125:100:100 NPK ha^{-1}) than conventional method of irrigation with soil application of fertilizers. This indicates drip fertigation with 125% N + 100% P+ 100% K in five splits shows 25 percent saving in fertilizer when applied through irrigation water compared to conventional soil application in drip irrigation.

Lowest grain and straw yield was observed in furrow irrigation with conventional application of fertilizers. Decreasing level of P and K fertigation from 100% to 75% resulted in significant decrease in grain yield.

Increased nutrient availability and absorption by the crop at the optimum moisture supply coupled with frequent and higher nutrient supply by fertigation and consequent better formation and translocation of assimilates from source to sink might have increased seed yield under fertigation. The results are in conformity with the findings of Praharaj and Kumar (2012), Vimalendran and Latha (2014), Chandra Sekhar (2014), Praharaj *et al.*, (2016), Vimalendran and Latha (2016).

It could be concluded that application of 125:100:100 per cent recommended dose of N, P and K in five splits found to be best for better uptake of major nutrients, WUE and maximizing the pigeon pea productivity through fertigation.

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