International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2020; 8(5): 1268-1272

Received: 19-06-2020
Accepted: 07-08-2020

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Response of drip fertigation and its interval on nutrient uptake, nutrient use efficiency, water use efficiency and yield of wheat (*Triticum aestivum* L.)

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DOI: https://doi.org/10.22271/chemi.2020.v8.i5r.10476

Abstract
A field investigation entitled "Response of drip fertigation and its interval on nutrient uptake, nutrient use efficiency, water use efficiency and yield of wheat (*Triticum aestivum* L.)" was carried out at Department of Agronomy Farm, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during the *Rabi* season of 2019-20. The experiment was laid out in Randomised Block Design with four replications and eight different irrigations and fertigation treatments imposed for wheat crop with an objective to study the nutrient uptake, nutrient use efficiency and water use efficiency through drip fertigation in wheat. The experimental site was established with inline drip irrigation system (16 mm) lateral laid out at 90 cm with 50 cm dripper spacing. Irrigation water was applied through drip irrigation system on every alternate day based on cumulative pan evaporation and surface irrigation water was applied at 1.0 IW/CPE ratio. Experiment results revealed that, in wheat crop the nutrients uptake was favourably increased with higher level of fertigation compared with lower levels and soil application method. During entire crop growth, higher uptake of N and K were observed at 100 per cent levels of N and K fertigation in 7 days interval which was at par with 100 per cent drip fertigation of RDNK in 14 days interval. Progressive increase in applied level of N and K correspondingly increased the nutrient uptake and lower uptake was noticed in conventional method of fertilizer application in surface irrigation. Water use efficiency was markedly improved by drip fertigation at higher level compared to conventional soil application and surface irrigation method. However, NUE showed increasing trend with increasing level of N and K, but lower NUE was observed in conventional method of fertilizer application. As a consequence of better nutrient uptake and WUE in treatment drip fertigation with 100 per cent RDNK in seven days interval recorded higher grain yield of 5653 kg ha^{-1} which was at par with 100 per cent drip fertigation of RDNK in fourteen days interval with grain yield of 5580 kg ha^{-1}. It could be concluded that application of 100 per cent RDNK in seven days interval found to be best and at par with 100 per cent RDNK in fourteen days interval for better uptake of nutrients, NUE, WUE and maximizing the wheat grain yield through fertigation.

Keywords: Drip, fertigation, NPK uptake, NUE, wheat, WUE

Introduction
Wheat (*Triticum aestivum* L.) is one of most important staple food crop of India grown in diverse agro-climatic condition. Wheat is a feeding bowl to mankind occupies a premier position of all the staple food grain crops. In India wheat is most important food after rice in term of both area and production which contributes 12% of the world wheat pool. In India during 2017-18 area under wheat cultivation was 309.60 Lakh hectare with annual production of 98.38 Lakh tons with an average productivity 3172 Kg ha^{-1}. In Maharashtra it occupies area of 12.72 Lakh hectare with production of 22.14 Lakh tons and average productivity is 1740 Kg ha^{-1}. (Ministry of Agriculture, New Delhi, Economics Times, Fourth Estimates 2017-18).
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 in wheat crop 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 at different intervals 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 wheat crop if applied through drip irrigation system. 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 wheat cultivation under water scarcity condition which will help to increase the per hectare 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. Wheat is very sensitive to insufficient N availability to wheat plants which results in low yields and significantly reduced profits compared to a properly fertilized crop (Singh *et al.* 2010) [19]. Nitrogen is widely used fertilizer nutrient in wheat, but highly susceptible to leaching losses, Fertigation has the potential to supply a right mixture of water and nutrients to the root zone, thus meeting plant water and nutrient requirements in most efficient possible manner with reduced losses.

Fertigation allows the crops to use up to 90 percent of the applied nutrients. Fertigation ensures saving in fertilizer (40-60 percent), due to "better nutrient use efficiency" and "reduction in leaching". (Kumar and Singh, 2002) [9]. The water and fertilizers are becoming costlier day by day and thus, there is a need of saving and efficient use of this resources without affecting the agricultural production and productivity. Hence, the present study was conducted to study the Response of drip fertigation and its interval on nutrient uptake, nutrient use efficiency, water use efficiency and yield of wheat (*Triticum aestivum* L.).

Materials and Methods

The field experiment was carried out at Agronomy Farm, Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during the *rabi* seasons of 2019-20. The topography of the field was fairly uniform and level. The soil was clay texture belonging to Vertisols. The experiment was laid out in randomised block design with four replications and eight different fertigation treatments imposed for wheat crop i.e. 100 per cent RDNK through soil application with surface irrigation (T_1), drip irrigation with 100 per cent RDNK through soil application(T_2), drip fertigation with 25 per cent RDNK in 7 days interval(T_3), drip fertigation with 25 per cent RDNK in 14 days interval (T_4), drip fertigation with 50 per cent RDNK in 7 days interval (T_5), drip fertigation with 50 per cent RDNK in 14 days interval (T_6), drip fertigation with 100 per cent RDNK in 7 days interval (T_7), drip fertigation with 100 per cent RDNK in 14 days interval (T_8). The experimental site was established with inline drip irrigation system (16 mm) lateral laid out at 90 cm with 50 cm dripper spacing. Irrigation water was applied through drip irrigation system on every alternate day based on cumulative pan evaporation determined by the following formula. (Michael, 2008) [12] and surface irrigation water was applied at 1.0 IW/CPE ratio.

$$V\ (lpd) = (ETo \times Kc \times A \times Wp) – (RE \times A)$$

Where,

V- Volume of water applied (litre/day/plant), ETo - Reference evapotranspiration (mm/day)

Kc - Crop factor, A - Area under crop (m^2) (Plant to plant spacing) × (Row to row spacing)

Wp – Wetted area fraction, RE – Effective rainfall in mm

The net depth of water to be applied in drip irrigation of alternate day was determined by the following formula. (Michael, 2008) [12]

$$D= (ETo\times Kc)-RE$$

Where

D- Net depth of water to be required (mm), ETO - Reference evapotranspiration

The sources of nutrients were urea (46% N), single super phosphate (16% P_2O_5), and murate of potash (60% K_2O) for nitrogen, phosphorus and potash, respectively. The fertilizer was applied as per the treatments. The total dose of phosphorus was applied as basal dose in all the treatments and N and K was applied in weekly split dosage through drip up to 84 DAS. In treatment T_1 and T_2, 50% nitrogen and 100% dose of phosphorus and potassium was applied as a basal dose and remaining 50% nitrogen was applied as 25% + 25% at 21 and 45 days respectively after sowing manually. The fertilizer tank of 90 litre capacity was used to apply chemical fertilizer through the irrigation water. The variety of wheat crop PDKV-SARDAR (AKAW 4210-6) was sown on 19th November 2019 with recommended dose of fertilizers 100:50:50 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 wheat was observed under various treatments. The total N, P and K uptake at harvest include the uptake by plant and grain as shown in Table 1.

Nitrogen uptake

In the present investigation, nitrogen uptake in wheat plant was more in grain than stalk. The different fertigation levels and soil application method showed significant influence on nitrogen uptake by plant. Successive increase in fertigation levels from 25 per cent to 100 per cent recommended dose of N and K (RDNK) resulted significant increase in total nitrogen uptake over its preceding lower level. Drip fertigation with 100 per cent RDNK in 7 days interval (T_7) found significantly higher total nitrogen uptake (159.00 $Kgha^{-1}$) compared to lower level of fertigation (T_5, T_6, T_3, T_4) and conventional method of fertilizer application in surface and drip irrigation (T_1 and T_2) but found at par with drip fertigation with 100 per cent recommended dose of N and K in 14 days interval (T_8). The drip fertigation with 50 per cent recommended dose of N and K in 7 and 14 days interval (T_5 and T_6) found comparable over drip fertigation with 25 per cent RDNPK in 7 and 14 days interval (T_3, T_4) and drip irrigation with 100 per cent RDNK through soil (T_2) application which was at par with each other and significant over soil application with surface irrigation (T_1). Similar results are in coinciding with Malve (2014) [11], Bhowmik *et al*. (2018) [4] and Jana *et al*. (2018) [8].

The concentration and availability of various nutrients in the soil for plant uptake depends on soil solution. 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. 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) [16]. Higher nutrient uptake with higher level of fertigation over soil application was also recorded by, Bhalerao *et al*. (2011) [3], Praharaj and Kumar (2012) [15], Results are in agreement with Fanish *et al*. (2011) [6], Zafari (2019) [21].

Phosphorus uptake

In the present Investigation it was observed that phosphorus uptake in wheat plant was was more in grain than stalk. Phosphorus uptake by grain, straw and total uptake was found maximum with treatments drip fertigation with 100 per cent RDNK in 7 days interval (T_7) and found at par with drip fertigation with 100 per cent RDNK in 14 days interval (T_8) which was found significantly superior over the rest of treatments. Lowest uptake was noticed in surface irrigation treatment (T_1) which was statistically inferior over other treatments and soil application with drip irrigation (T_2). Successive increase in irrigation levels from T_2 to T_8 resulted in significant increase in total phosphorus uptake over its preceding lower level. Similar findings were in corroborate with Majeed *et al*. (2014) [10], Malve *et al*. (2014) [11], and Bhowmik *et al*. (2018) [4].

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 wheat. The enhancement effects of increasing the amount of irrigation water on both P availability and uptake during the growth period. (Eissa *et al*. 2014) [5]. Fertilizers are considered different from the other nutrient carriers in that they are less mobile, less soluble and highly prone to fixation by the soil constituents, hence inefficient P use with surface application of dry P fertilizer results in excessive P fixation in soil and less consumption by crops, Zafari *et al*. (2019) [21].

Potassium uptake (kg ha^{-1})

In the present Investigation, Potassium uptake in wheat plant was more in stalk than in grain at harvest. Different fertigation levels and soil application of fertilizer in surface and drip method showed significant influence on potassium uptake by plant similarly to nitrogen and phosphorus uptake. The different fertigation levels and drip irrigation shows the significant impact on potassium uptake by plant similarly to nitrogen and phosphorus uptake. Successive increase in fertigation levels from 25 per cent to 100 per cent RDNK ha^{-1} resulted significant increase in potassium uptake over its preceding lower levels. Drip fertigation with 100 per cent RDNK in 7 days interval (T_7) found significantly higher potassium uptake compare to conventional method of fertilizer application (T_1 and T_2) and lower levels of fertigation (T_3, T_4, T_5 and T_6) but found at par with drip fertigation with 100 per cent RDNK in 14 days interval (T_8).

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 potassium fertilizers do not cause any precipitation as salts. 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 resulted in higher uptake by plants. Similar results were in agreement with Raskar (2004) [16], Bhalerao *et al*. (2011) [3], Praharaj and Kumar (2012) [15] in respect of more K uptake due to higher level of fertigation over soil application by conventional method and lower levels of fertigation.

Table 1: Influence of different fertigation treatments on NPK uptake (kg ha^{-1}) of wheat crop

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 - Surface irrigation + 100% RDF through soil application	56.65	26.85	83.51	9.43	6.39	15.83	24.40	46.88	71.28
T_2 - Drip irrigation + 100% RDF through soil application	78.05	36.74	114.79	14.45	9.13	23.59	33.33	59.17	92.50
T_3 - Drip fertigation with 25% RDNK (Once in 7 Days)+ 75% RDNK through soil application.	80.15	39.26	119.41	15.14	9.22	24.36	34.35	60.36	94.72
T_4 - Drip fertigation with 25% RDNK (Once in 14 Days)+75% RDNK through soil application	79.42	37.63	117.04	15.05	9.17	24.22	34.14	60.08	94.22
T_5 - Drip fertigation with 50% RDNK (Once in 7 Days) + 50% RDNK through soil application.	93.01	45.64	138.65	18.10	11.25	29.35	39.88	71.13	111.01
T_6 - Drip fertigation with 50% RDNK (Once in 14 Days)+ 50% RDNK through soil application.	91.17	44.71	135.88	17.85	11.12	28.97	39.33	69.59	108.92
T_7 - Drip fertigation with 100% RDNK (Once in 7 Days)	105.42	53.59	159.00	21.10	13.34	34.44	45.22	80.84	126.06
T_8 - Drip fertigation with 100% RDNK (Once in 14 Days)	104.06	52.64	156.70	20.83	13.22	34.05	44.64	80.11	124.75
S.E(m)±	3.54	2.09	5.51	0.75	0.61	1.42	1.65	2.96	4.59
C.D. at 5%	10.43	6.15	16.22	2.21	1.81	4.18	4.87	8.71	13.51

Table 2: Water use efficiency, nutrient use efficiency and yield of wheat as influenced by different fertigation treatments

Treatments	WUE(kg ha^{-1}mm)	NUE (kg kg^{-1})	Wheat Grain yield (kg/ha)
T_1 -Surface irrigation + 100% RDF through soil application	9.04	16.2	3253
T_2 -Drip irrigation + 100% RDF through soil application	21.97	21.6	4328
T_3 - Drip fertigation with 25% RDNK (Once in 7 Days)+ 75% RDNK through soil application.	22.36	22.0	4404
T_4 - Drip fertigation with 25% RDNK (Once in 14 Days)+75% RDNK through soil application	22.22	21.8	4377

T_5 - Drip fertigation with 50% RDNK (Once in 7 Days) + 50% RDNK through soil application.	25.63	25.2	5049
T_6 - Drip fertigation with 50% RDNK (Once in 14 Days)+ 50% RDNK through soil application.	25.27	24.8	4979
T_7 - Drip fertigation with 100% RDNK (Once in 7 Days)	28.70	28.2	5653
T_8 - Drip fertigation with 100% RDNK (Once in 14 Days)	28.33	27.9	5580
S.E.m±	--	--	175
CD at 5%	--	--	514

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

In the present investigation, there was a positive relation among increasing drip fertigation level and wheat grain yield. The highest WUE (28.70 kg ha^{-1} mm) was registered under drip fertigation at 100 per cent RDNK ha^{-1} in 7 days interval followed by 100 per cent RDNK ha^{-1} in 14 days interval (28.33 kg ha^{-1} mm). Drip fertigation levels of RDNK from 25 per cent to 100 per cent level showed progressive increase in WUE during the study. The conventional method of surface irrigation with 100 per cent recommended dose of fertilizers through conventional soil application recorded lower WUE (9.04 kg ha^{-1} mm) than soil applied drip irrigation and fertigation levels of 25,50 and 100 per cent RDNK ha^{-1}. Thus, the increased in WUE in fertigation over surface irrigation method was thrice in drip fertigation at 100 per cent RDNK in 7 and 14 days interval.

Nitrogen and potassium applied through drip irrigation had distinct bearing as evident from higher WUE with higher level of RDNK ha^{-1} by drip fertigation (100 per cent). Markedly higher WUE was associated with higher level of drip fertigation than lower level. Because of adequate and timely availability of water and nutrients and their positive interaction might have stimulated the early growth and increased leaf surfaces for photosynthesis and ultimately increased the yield to record higher WUE under drip fertigation with higher levels compared to soil application of fertilizers Fanish *et al*. (2011) [6], Gokila (2012) [7] and Umair *et al*. (2019) [20] recorded the similar finding of increasing WUE with increasing level of fertigation.

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

The data on nutrient use efficiency of wheat crop under drip fertigation as influenced by different treatments are presented in Table 2. Drip fertigation with 100 per cent recommended dose of N and K in 7 days interval recorded a higher NUE of 28.2 kg wheat grain kg^{-1} followed by 27.9 kg kg^{-1} in 100 per cent RDNK in 14 days interval and lower levels. The higher nutrient uptake at higher fertigation doses i.e. 100 per cent RDNK fertigation has resulted in higher nutrient use efficiency. The trend of increasing NUE is parallel to the fertigation doses as increase in dose shows increasing nutrient use efficiency. The conventional method of soil application of fertilizers at 100 per cent RDF ha^{-1} with surface irrigation (T_1) has resulted lower NUE of 16.2 kg kg^{-1} wheat grain yield than all the fertigation treatments which clearly indicates the superiority of drip fertigation over conventional soil application with conventional method of surface irrigation of N and K fertilizers. Sandal *et al.* (2015) [18], revealed that fertigation ensures availability of fertilizer nutrients in the root zone in readily available form and therefore minimize fertilizer application rate and increases fertilizer use efficiency. These results are in accordance with the findings Gokila (2012) [7], Pawar *et al*. (2013) [13, 14], Rekha *et al*. (2015) [17].

Effect on wheat Yield

Effect of higher levels of fertigation at 100 per cent RDNK in 7 and 14 days interval promoting the growth and yield parameters of the crop had positive impact on the final grain yield. The grain yield linearly increased with increasing levels of fertilizers applied through fertigation. Drip fertigation at 100 per cent RDNK in 7 days interval had recorded higher grain yield of 5653 kg ha^{-1} which was followed by 100 per cent drip fertigation of RDNK in 14 days interval with grain yield of 5580 kg ha^{-1} and drip fertigation with 50 per cent recommended dose of N and K in 7 and 14 days interval with grain yield of 5049, 4979 kg ha^{-1} respectively. Drip fertigation at 25 per cent RDNK ha^{-1} in 7and 14 days interval recorded comparable yield with drip irrigation with 100 per cent recommended dose of N and K through fertigation when compared to conventional soil application of fertilizers. Drip fertigation at higher level of 100 per cent fertigation recorded higher harvest index and recorded an increased yield of 73.77 per cent over surface irrigation with 100 per cent recommended dose of NPK. Similar trend was noticed in respect of straw yield and biological 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 grain yield under fertigation. The results are in conformity with the findings Pawar *et al*. (2013) [13, 14] Malve *et al*. (2014) [11], Abdullah (2015) [1], Bhowmik *et al*. (2018) [4].

Conclusions

It could be concluded from the study that drip fertigation with 100% recommended dose of N and K in 7 days interval found to be best treatment which is at par with 100% RDNK in 14 days interval for better uptake of major nutrients, NUE, WUE and maximizing the yield and productivity of wheat through fertigation.

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