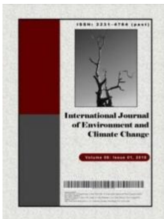

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Drip Irrigation Scheduling for Higher Growth, Productivity and Input Use Efficiency of Direct Seeded Basmati Rice in Indo-Gangetic Plains for Climate Resilient

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Authors' contributions

This work was carried out in collaboration between all authors. Authors AKB and PS designed the study, performed the statistical analysis and wrote the protocol. Authors TP, RKB and TCS wrote the first draft of the manuscript. Authors AKB and TP managed the analyses of the study. Authors RKB and TCS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The Indo-Gangetic plain (IGP) is an environmentally susceptible, communally momentous and economically tactical sphere of India where landscape, ground water and soil fertility are threatened by climate change. An increasing water scarcity for rice in the irrigated IGP is urging farmers to espouse water saving technologies such micro irrigation. Rice growing with drip irrigation may substantially reduce irrigation water requirement of rice. In order to make assessment of drip irrigation in rice, a field experiment was carried out at Pantnagar, Uttarakhand in 2017. Rice was established by Direct Seeding in conventional and drip irrigation treatments. The treatments were laid with drip irrigation at 50, 75 and 100% CPE on each 2 and 4 days interval. Two conventional irrigation practices (i.e. absolute control and farmers' practice) were also included in the study. The experiment was laid out in randomized block design with four replications. Compared with farmers practice, (transplanted and flooded) drip irrigation at 100% CPE on two days interval produced taller shoots and higher yield attributes of rice crop. Rice grown in drip irrigation was found more grain yield than farmers' practice. Among drip irrigation, 100% CPE on 2 days gap (T_5) recorded 45% higher grain yield (5800 kg ha^{-1}) than farmers practice. Similarly, T_5 treatment was higher content and uptake of nutrient. However, treatments T_3 (50%

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CPE on 2 days gap) followed by T_7 (75% CPE on 4 days interval) had higher water use efficiency. Result, further revealed that fertilizer use efficiency of T_5 treatment was found to be higher (23.2 kg grain per kg fertilizer applied). Hence, rice is scheduled with drip irrigation at a tune of 100% CPE on 2 days interval can benefit over sustaining the direct seeded basmati rice productivity. However, there is a demand to examine these benefits of drip irrigation in rice in relation to the viability of adoption by farmers.

Keywords: Drip irrigation; nutrient; rice; WUE; yield.

1. INTRODUCTION

Rice is a primary stable food for many people in the world. In Asia, about 7 billion peoples live in rice predominant growing areas and rice is their core source of calories [1]. The rice cultivated land in India has increased from 30.81 m ha in 1950-51 to 43.86 m ha in 2014-15 which is roughly 142% higher. The rice production in country has registered an appreciable increase from 20.58 mt in 1950-51 to 104.86 mt during 2014-15, which is nearly about 5 times. The yield was 668 kg ha^{-1} in 1950 -51 which has increased to 2390 kg ha^{-1} during 2014-15 [2]. The notable progress achieved after green revolution in country is attributed to the development and large scale adoption of semi dwarf high yielding varieties, fertilizer responsive varieties and irrigation development methods of sowing all together with harmonizing production and protection technology. Aroma rice especially basmati engage unique position in rice crop production and is privileged by people because of its excellent cooking quality and scent. India is the biggest producer and exporter of basmati rice in the world. The export of basmati rice in the year of 2015-16 was 2.37 mt. Owing to its outstanding in export potential and elevated market value, growing area of basmati rice has been increased to 20% of total rice area (5.60 lakh ha).

An unexpected change in the monsoon could precipitate a major crisis, triggering more frequent droughts as well as greater flooding in large parts of India. Analysing a trend of rising temperature and declining rainfall during 1970-2015, observed that during the years when rainfall levels drop 100mm below average, farmer incomes would fall by 15 percent during the kharif and seven percent during the rabi crops seasons. The survey points out that climate change could reduce annual agricultural incomes in the range of 15 percent to 18 percent on an average and up to 20-25 percent for unirrigated areas. It stresses that climate change will increase farmer uncertainty and called for effective crop insurance and the use of technology to make farming resilient. This may have grave endangered on food security in several countries. The survey suggests minimising susceptibility to climate change require drastically extending irrigation via efficient drip and sprinkler technologies. Drip irrigation system approaching strongly as competent system for irrigating the rice crop with more efficient in irrigation water application as well as more eco-friendly in function and management. Nearly 5.0 to 6.5 t ha^{-1} of paddy could harvest through the drip irrigation system with fifty to sixty lakh litres of water. This was more efficient than the conventional method [3]. So, with MIS, we possibly shift towards “more crop per drop”. Because of a massive curtail in evaporation, percolation and seepage, drip irrigation allow for higher water use efficiency as well as high water saving as compared to conventional flooded irrigation [4]. To date with the scenario of diversified cropping systems and declining ground water table in the Indo-Gangetic plains, growing of basmati rice can be of immense value since it required minimum water than that of rice and is transplanted late when monsoons starts in, as a result saving a huge water. Cultivation of basmati rice can reduce in use of irrigation water as well as play a significant role in diversification of crops. Field evaluation of water usage of different crops, such as banana, sugarcane, cotton, vegetable and orchards plantation crops, suggest that different approach of irrigation considerably influence the growth and WUE of crops, with higher water productivity and crop productivity achieved under drip irrigation system than under traditional furrow and sprinkler irrigation [5,6]. Soman et al. [7] reported 44.8 and 11.7% more rice grain yield in drip irrigation as compared to flood and sprinkler irrigation methods, respectively. However, studies of efficient use of irrigation water and water saving technologies in rice crop production systems have largely focused on innovations in farming systems which include furrow and sprinkler irrigation systems [8,9,10] with almost no studies of water saving technologies had been made under basmati in drip irrigation. So, it is vital to understand the production as well as WUE of basmati rice crop under the drip irrigation system. Besides, there is small information concerning whether basmati rice, like other crops such as banana, sugarcane, cotton and vegetables, has higher productivity and WUE under drip irrigation system than under furrow method irrigation, or whether rice grown with drip irrigation has higher grain production potential as compared with that of traditional water saving technologies. Taking these points into account, a field study was conducted to evaluate the effects of drip irrigation as compared with conventional flood irrigation on yield and input use efficiency of basmati rice.

2. MATERIALS AND METHODS

The field experiment was conducted during Kharif season at University Farm, G.B.P.U.A.T, Pantnagar, India which is located around the point of at 29º N latitude, 79^{0}.29'E longitude and at 243.84 m above MSL. During the study period year, the mean maximum and minimum temperature were 38.4 and 26.1ºC, respectively, mean relative humidity was 69.3%, total rainfall and effective rainfall were 1247 and 623 mm, respectively. The soil was classified as mollisol. The soil was silty clay loam in nature. The soil was high in organic carbon and available P and medium in K and low in available N.

The research experiment was designed in randomized block with 4 replications. The treatments were consisted of conventional and drip irrigation practices for Direct Seeded Basmati rice crop. Treatments in conventional irrigation practice include rice grown without fertilizers as absolute control (T_1) and conventionally puddled followed by transplanted with recommended fertilizers as farmer's practice (T_2). Whereas, treatments in drip irrigation (T_3 to T_8), direct seeding rice planted under drip irrigation had provided at 50, 75 and 100% CPE after 2 and 4 days intervals making a total of eight treatments.

Rice variety Pant Basmati-1 was sown as direct seeded in 2017 with seed rate 25 kg ha^{-1} at 20×10 cm spacing. The plots were of size 9 m × 4 m and crop was raised with recommended package of practices. In order to ensure ideal condition for proper germination, pre sowing irrigation was given. Irrigations were given through drip system based on daily open pan evaporation values were measured from Crop Research Centre of the university. While, conventional method, irrigations were applied with 3-4 cm depth in each irrigation through irrigation channels until flowering stages.

The volume of irrigation water by one lateral in different irrigation treatments were calculated as:

$$V = r.\, E_o.\, K_{pan}.\, K_c.\, A$$

Where, V - Volume of water to be delivered by one lateral (lpH), E_o is USWA open pan evaporation (mm/day), K_{pan} is Pan coefficient, K_c is Crop co-efficient, r is Unit constant, A is Area covered by one lateral (m^2).

Then, time of drip system operation to deliver the required volume of irrigation water from single lateral as per the irrigation treatment was calculated as:

$$\text{Time of operation (Hours)} = \frac{\text{Volume of water to be delivered (V) by one lateral (l)}}{\text{Emitter discharge rate (lpH) x Number of emitters}}$$

The crop was raised with uniform fertilizer dose of 150-60-40 kg NPK kg^{-1} ha^{-1}. For the treatments of conventional irrigation practices, half dose of nitrogen and full dose of phosphorus and potassium in the form of urea, DAP and MOP, respectively were applied during sowing time and remaining half dose of N was given in two equal splits during active tillering and panicle initiation stages as per the treatments. Fertigation for N (urea), P (phosphoric acid) and K (white potash) was scheduled with once in a week up to 17, 4 and 7 weeks of crop season, respectively. All the cultural operations were carried out as per general recommendations. The rice crop was harvested by hand using sickle when grains nearly matured and straw had changed yellowish colour. Data on biological yield, test weight and harvest index were recorded. Water use efficiency was computed by dividing grain yield and quantity of water used. The obtained data were statistically analysed by two-way Analysis of Variance (ANOVA) following the method of Gomez and Gomez [11].

3. RESULTS AND DISCUSSION

3.1 Yield Characters of Basmati Rice

The rice grain, straw and biomass yield was significantly influenced by the different treatments in the present investigation (Fig. 1). Increases in irrigation water amount caused by different drip irrigation treatments were significantly reflected in the grain yield of rice which was significantly higher in drip irrigation than in flood irrigation (control plots). During the experimentation, treatments in drip irrigation except T6 treatment did not show significant difference in grain yield. A higher rice grain yield was recorded in T_5 treatment followed by T_4, T_8, T_7, and T_3 treatments. Compared with farmers' practice (T_2), the mean basmati rice yields with T_5, T_4, T_8 and T_7 treatments were significantly increased by 5800 kg ha^{-1} (45.0%), 5740 kg ha^{-1} (43.5%), 5700 kg ha^{-1} (42.5%) and 5650 kg ha^{-1} (41.3%), respectively.

Drip irrigation attributed more grain yield due to its superiority in producing higher productive tillers, length of panicle, seed test weight and filled grains $panicle^{-1}$ with lower % chaffyness than the flood irrigation treatment. Further, drip irrigation is facilitating constant water availability to the plant roots vicinity and thus, plant always be growing with optimum soil moisture and proper aeration in the soil resulted in higher root growth and grain yield. These findings are consistent with the results reported by Yang et al. [12] indicating that intermittent irrigation and maintaining moist, mostly aerobic soils not only boosting yield characters but also the root system's development and functioning. Rice grown in direct seeded with drip irrigation produced grain yield varied from 15.73 to 35.31% over the conventional irrigation transplanted rice [13]. These findings were in agreed with the study of Viraktamath [14] and Soman [15].

Straw yield was higher in drip irrigation treatments than in farmers' practice rice. Among drip irrigation treatments, higher straw yield of rice was recorded in T_5 treatment followed by T_4, T_8 and T_7 treatments, however, all these were significantly equal. The higher straw yield under drip irrigated rice was apparently related to their higher shoot height, high tiller density per unit area. The same result also confirmed by Tripathi et al. [16] that higher straw yield observed at optimum moisture condition than flooded rice. Compared with farmers' practice (T_2), the mean biomass yields with T_5, T_4, T_8 and T_7 were significantly increased by 14000 kg ha^{-1} (41.4%), 13680 kg ha^{-1} (14.2%), 13400 kg ha^{-1} (35.4%) and 13200 kg ha^{-1} (33.3%), respectively.

3.2 Yield Attributes

Plant height of basmati rice was more in T_5 treatment by 14.7% as compared to farmers practice (T_2) and it was closely followed by T_4 treatment. Crop grown with favourable environment under drip irrigation treatment could achieve higher plant height than farmers practice plot. Yield attributes i.e. effective tillers m^{-2}, number of panicle m^{-2}, weight of panicle, number of grains $panicle^{-1}$ and 1000 grain weight at harvest were differently affected by various irrigation methods (Table 1). During the study period, all drip irrigation treatments were recorded higher effective tillers m^{-2}. Significantly higher effective tillers m^{-2} under drip irrigation than conventional method of irrigation indicates that optimum soil moisture ensures better plant population and stand establishment of rice. T_5 treatment had recorded higher effective tillers among different drip irrigation methods followed by T_4 treatment; however, it was closely with T_8 treatments. Similar results were also observed for number of panicles m^{-2} of rice in this experiment. Panicle weight and number of grains per panicle are directly related to rice grain yield. Drip irrigation treatments brought about significant higher value of number of grains per panicle and panicle weight than flood irrigation method. Among drip irrigation, the both panicle weight and number of grains per panicle were gradually and significantly increased with T_5 treatment followed by T_4 and T_8 treatments. In the present study, both control treatments comparatively showed less panicle weight and number of grains per panicle. With regards to number of grains per panicle and 1000 grain weights, the T_5 treatment produced significantly higher than other treatments. The number of grains per panicle and 1000 grain weight was least under T_1 and T_2 treatments. In general, all rice attributing characters under drip irrigation was found to be superior over farmers' practice. Superior characteristics of yield attributes under drip irrigation might be due to even distribution of water with adequate availability and enhanced favorable rhizosphere for more nutrients uptake which in turn accelerate the growth, leading to the formation of higher yield attributes in the course of contribute of more photosynthates towards the sink. These findings are in close accordance with Chouhan et al. [17].

3.3 Water Use and Input Use Efficiency

Higher water use efficiency (WUE) in drip fertigation is probable as the volume of water applied through drip system roughly corresponds to the consumptive use of plants. Consistent with this, total water used was highest in surface irrigation method (2213 mm) when compared to different levels with drip fertigation (711 to 802 mm) (Table 2). Further, water saved over flood irrigation method was varied from 88.74% in T_5 to 94.47% as in T_6 treatment. In case of WUE, basmati rice irrigated in 50% (T_3) and 75% (T_7) CPE on 2 or 4 days gap treatments recorded significantly higher WUE (7.50 and 7.49 kg ha-mm^{-1}, respectively), followed by 75% (T_4) and 50% (T_6) CPE on 2 or 4 days gap treatments. The lowest WUE was observed when the crop with surface irrigation (T_1 and T_2 treatments) of conventionally flooded rice (0.99 and 1.81 kg ha-mm^{-1}). Increase in WUE in drip irrigation system over flood irrigation was mainly due to the controlled water release near the crop rhizosphere zone [18]. Water saving of 79 to 90% was achieved with drip irrigation along with direct seeding followed in rice cultivation [19]. It is also due to higher yield levels due to higher nutrients uptake by crop as a result of timely and frequent supplementation of water as well as nutrients to root zone leading to the decrease in leaching and volatilization losses of nutrients.

Table 1. Yield attributes of Basmati Rice as affected by irrigation scheduling treatments through Drip Irrigation

Treatments	Plant height (cm)	No. of tillers m^{-2}	No. of panicle m^{-2}	Average panicle weight (g)	No. of grains panicle^{-1}	1000 grain weight (g)
Control (T_1)	104^{d}	401^{e}	324^{c}	2.15^{e}	105^{c}	15^{a}
Transplanted & Flooded (T_2)	118.93^{c}	455^{d}	330^{bc}	2.28^{d}	131^{b}	18^{cd}
Drip Irrigation at 50% CPE 2 days gap (T_3)	125.90b^{c}	469^{bcd}	331^{bc}	2.40^{c}	139^{b}	21^{bc}
Drip Irrigation at 75% CPE 2 days gap (T_4)	130.75^{ab}	490^{ab}	375^{a}	2.50^{b}	145^{b}	23^{ab}
Drip Irrigation at 100% CPE 2 days gap (T_5)	136.45^{a}	501^{a}	390^{a}	2.80^{a}	390^{a}	26^{a}
Drip Irrigation at 50% CPE 4 days gap (T_6)	124.48^{bc}	460^{cd}	330^{bc}	2.28^{d}	135^{b}	20^{bc}
Drip Irrigation at 75% CPE 4 days gap (T_7)	126.13^{bc}	474^{bcd}	341^{bc}	2.42^{bc}	139^{b}	22^{bc}
Drip Irrigation at 100% CPE 4 days gap (T_8)	127.45^{b}	485^{abc}	362^{ab}	2.48^{bc}	144^{b}	22^{bc}

Treatments means followed by common letter (s) are not significantly different among each other according to LSD test

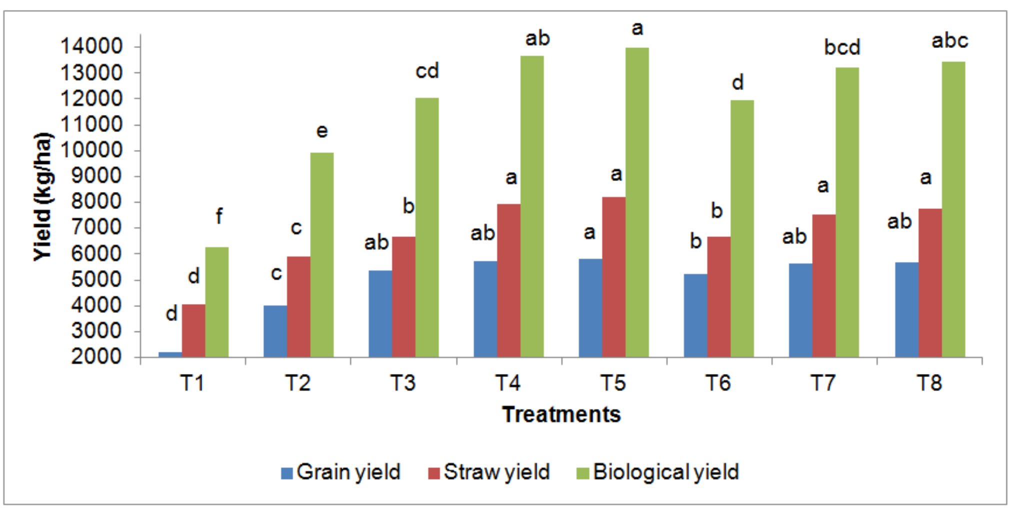

Fig. 1. Grain, Straw and Biological yield characters of Basmati Rice as affected by Drip Irrigation treatments. Treatments means followed by common letter (s) are not significantly different among each other according to LSD test

Table 2. Fertilizer and water use efficiency in Basmati Rice as affected by different irrigation scheduling treatments through drip irrigation

Treatments	Total water used inclusive of effective rainfall (mm)	Water use efficiency (kg ha-mm^{-1})	% saving of irrigation water over farmers' practice	Total fertilizer used (kg ha^{-1})	Fertilizer used efficiency (kg grain/ kg fertilizer)
Control (T_1)	2213	0.99	-	0	-
Transplanted & Flooded (T_2)	2213	1.81	-	250	16.00
Drip Irrigation at 50% CPE 2 days gap (T_3)	713	7.50	94.34	250	21.40
Drip Irrigation at 75% CPE 2 days gap (T_4)	772	7.44	90.63	250	22.96
Drip Irrigation at 100% CPE 2 days gap (T_5)	802	7.23	88.74	250	23.20
Drip Irrigation at 50% CPE 4 days gap (T_6)	711	7.38	94.47	250	21.00
Drip Irrigation at 75% CPE 4 days gap (T_7)	754	7.49	91.76	250	22.60
Drip Irrigation at 100% CPE 4 days gap (T_8)	798	7.14	88.99	250	22.80

Table 3. Nitrogen, Phosphorus and Potassium uptake (kg ha^{-1}) by Basmati Rice as influenced by different irrigation scheduling through Drip irrigation

Treatments	Nitrogen	Phosphorus	Potash
Control (T_1)	66.75^{d}	36.06^{d}	66.10^{e}
Transplanted & Flooded (T_2)	104.83^{c}	55.78^{c}	93.12^{d}
Drip Irrigation at 50% CPE 2 days gap (T_3)	122.63^{b}	71.49^{b}	117.18^{bc}
Drip Irrigation at 75% CPE 2 days gap (T_4)	141.38^{a}	73.71^{b}	126.01^{b}
Drip Irrigation at 100% CPE 2 days gap (T_5)	141.41^{a}	79.51^{a}	140.95^{a}
Drip Irrigation at 50% CPE 4 days gap (T_6)	121.74^{b}	67.89^{b}	105.56^{c}
Drip Irrigation at 75% CPE 4 days gap (T_7)	133.44^{a}	72.28^{b}	119.32^{b}
Drip Irrigation at 100% CPE 4 days gap (T_8)	141.04^{a}	73.02^{b}	124.85^{b}

Treatments means followed by common letter (s) are not significantly different among each other according to LSD test

Table 4. Concentration of Nitrogen, Phosphorus and Potash (per cent) in basmati rice as affected by different irrigation scheduling treatments through Drip irrigation

Treatments	Nitrogen	Phosphorus	Potash
Control (T_1)	1.81^{f}	1.02^{e}	1.63^{c}
Transplanted & Flooded (T_2)	1.85^{e}	1.02^{ce}	1.64^{c}
Drip Irrigation at 50% CPE 2 days gap (T_3)	1.88^{d}	1.04^{c}	1.67^{bc}
Drip Irrigation at 75% CPE 2 days gap (T_4)	1.92^{b}	1.07^{a}	1.81^{ab}
Drip Irrigation at 100% CPE 2 days gap (T_5)	1.97^{a}	1.11^{a}	1.85^{a}
Drip Irrigation at 50% CPE 4 days gap (T_6)	1.88^{d}	1.04^{c}	1.65^{c}
Drip Irrigation at 75% CPE 4 days gap (T_7)	1.90^{c}	1.05^{bc}	1.74^{abc}
Drip Irrigation at 100% CPE 4 days gap (T_8)	1.91^{bc}	1.06^{ab}	1.77^{abc}

Treatments means followed by common letter (s) are not significantly different among each other according to LSD test

Fertilizer use efficiency (FUE) based on grain yields were affected by different irrigation levels of water through drip and flood methods in study period. Fertilizer is used efficiently while a great fraction of the applied fertilizer is taken up by the crop and there is a huge enhance in yield for each unit of fertilizers applied. In present investigation, the FUE for grain production was higher in 100% CPE at 2 days gap (T_5) treatment (23.20 kg grain kg fertilizer^{-1}) followed by 75% CPE (T_4) (22.96 kg grain kg fertilizer^{-1}), 100% CPE (T_8) (22.80 kg grain kg fertilizer^{-1}) and 75% CPE at 4 days gap (T_7) (22.60 kg grain kg fertilizer^{-1}), with the lowest in T_2 (16.00 kg grain kg fertilizer^{-1}) in kharif season growing basmati rice. In general, the higher FUE in drip irrigation particularly in T_5 treatment (100% CPE at 2 days gap) was primarily due to higher yield with more efficient use of applied fertilizer in plots. In contrast, low FUE of T_2 treatment under flood irrigation method was due to more loss of applied fertilizer through leaching, denitrification and volatilization occurs in the study field. The favourable effect of water and nutrients on crop growth and grain yield in drip irrigation probably resulted in higher FUE [20]. These results are in accordance with findings of Abdelraouf [21].

3.4 Nutrient Uptake

For calculating nutrient uptake, grain and straw of basmati rice were considered. Rice grown with drip irrigation was found to be significant higher nutrient uptake than flood irrigation method (Table 3). During the experiment, nitrogen uptake was highest (141.41 kg ha^{-1}) in T_5 100% CPE treatment, followed by T_4 75% CPE at 2 days gap (141.38 kg ha^{-1}), T_8 100% CPE (141.04 kg ha^{-1}) and T_7 75% CPE at 4 days gap (133.44 kg ha^{-1}); however, it was not significantly varied with each other. Uptake of P and K was more or less same in rice. P and K uptake was significantly highest in T_5 treatment 100% CPE followed by T_4 75% CPE, T_8 100% CPE and T_7 75% CPE at 4 days gap treatments. Rice crop irrigated with conventional method i.e. Control (T_1) and conventional irrigated crop (T_2) treatments had recorded lower uptake of NPK nutrients.

Crop grown with better soil moisture and good aeration and fragment N.P.K. application as fertigation all higher various growth stages under drip irrigation could have facilitated to uptake more nutrients due to more root proliferation of active roots found in vicinity of nutrient available zone environments. The similar result was also reported by Saharawat et al. [22].

3.5 Nutrient Concentration

The data illustrated in Table 4 show the nitrogen (N), phosphorus (P), and potassium (K) concentrations in the grain and straw at harvest stage of rice as affected by different irrigation levels through drip and flood irrigation methods. The supply of irrigation through drip significantly influenced the concentrations of N, P, and K in rice crop. The highest significant values of N, P and K concentrations were obtained when rice supplied with irrigation in T_5 (100% CPE at 2 days gap) treatment. The supplement of irrigation water with a tune of 100% CPE at 2 days gap i.e. T_5 treatment increased the concentrations of N by 6.5 % compared to the conventionally flooded (T_2) treatment. Followed by treatments of T_4 75% CPE at 2 days gap , T_8 100% CPE at 4 days gap and T_7 75% CPE at 4 days gap were increased nitrogen concentration by 3.8%, 3.2% and 2.7%, respectively. Similarly, the T_5 and T_4 treatments increased the concentrations of P by 8.8 and 4.9% as compared to the T_2 treatment. The same trends were followed for K concentration. In general, the concentrations of N, P and K in the grain and straw of drip irrigated basmati rice responded to all the studied irrigation levels and the highest significant values were recorded when irrigation applied with a tune of 100% CPE at two days interval period. Campbell et al. [23] reported that plant absorbs nutrients more with irrigated by drip irrigation and found more nutrient concentration in plant parts.

4. CONCLUSION

In this study, the amalgamation of drip irrigation along with recommended fertilizer dose has shown large irrigation water savings (88–94%) compared to the present continuously flooded wet seeded rice cultivation practices in IGP area. Further drip irrigation with a tune of 100 or 75% CPE on 2 days gap resulted in considerable gain in rice yield by 43-45% over farmer's practice of flooded crop and favourable traits, which appeared to be due to water applied at optimum quantity in entire growing period. The prosperity of rice cultivation was not encumbering for adopting drip irrigation, with an enormous advantage of savings in water against climate change and labor resources also. Moreover, there is need to validate this technology through a farmers' participatory approach in diverse agro-ecological environment.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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