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Optimizing nutrient absorption in basmati rice: A study on drip irrigation and fertigation methods

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Abstract
Transplanting rice cultivation is causing a fast depletion of groundwater. The goal of the drip method used nowadays is to produce more rice with less water. India has 143 million hectares of arable land, which presents a huge opportunity for micro irrigation. An environment that is favourable for roots to absorb nutrients and moisture is produced by drip irrigation. It was demonstrated that 100% NPK significantly increased grain absorption when compared to 50% and 75% NPK level. In comparison to the drip method, the flood approach showed lower N, P, and K absorption by rice grains and straw in 2016 and 2017.

Keywords: Drip, flood, yield, content, grain and straw

Introduction

Rice is one of the world's most important staple crops, providing a substantial source of food and money for millions of people. FAO (2022) [8] reported that 509 million metric tons of rice were produced worldwide with China, India, and Indonesia being the world's top producers. Additionally, rice is a necessary commodity for food security, especially in South East Asia, which produces more than 90% of the world's rice (Cheng *et al*., 2020) [6]. Among the rice varieties, Basmati rice is gaining popularity across the world because of its distinct characteristics. With over 70% of the global output of basmati rice, India leads the globe in this regard, with Pakistan in second (Kumari *et al*., 2022) [15]. India is the biggest exporter of basmati rice with 70% of the world’s basmati export (ITC, 2021) [12].

Although traditional rice cultivation techniques have been used for many years, there are several drawbacks that hinder productivity and sustainability such as pests and diseases, water scarcity, changing land uses, and climate change, are posing a threat to rice production (Zhang *et al*., 2019; Hussain *et al*., 2020) [25, 11], uneven plant spacing, which can result in lower yields and poorer-quality grains (Phung *et al*., 2017) [18], excessive use of water and fertilizer, which can degrade the environment and reduce profitability (Lin *et al*., 2018) [17], manual labor, which can be labor-intensive and time-consuming and puddling, which can cause compaction and soil degradation (Chowdhury *et al*., 2019) [7]. Farmers experience social and economic injustices as a result, in addition to higher production costs (Chen *et al*., 2019) [5].

Alternative growing techniques, such direct planting, have been studied recently since they can increase yield and profitability while requiring less work and water (Xu *et al*., 2021) [23]. As an alternative to conventional techniques, the use of drip irrigation for direct rice sowing has gained popularity in recent years. South East Asian rice growers found drip irrigation to be a desirable alternative as it uses water more effectively and requires less effort (Hang *et al*., 2022) [10]. Drip irrigation consistently increased rice yield, water use efficiency, and nutrient uptake when compared to conventional methods (Gao *et al.* (2017) [9]; Zhang *et al.* (2018) [24]; Rahman *et al.* (2019) [19] and Li *et al.* (2020)) [16].

In developing countries, fertilizer is applied unevenly and in insufficient amounts that led to poor efficiency of nutrients and drip irrigation has potential in rice farming for raising nutrient use efficiency (Kumar (2009); Singh *et al.* (2019)) [14, 20]. Nitrogen is the most significant and effective nutrient among the others, controlling vegetative growth and grain yield to a significant degree.

It is a necessary component of many plant hormones, nucleic acids, amino acids, chlorophyll, and ATP, among other cell compounds (Wang *et al*., 2021) [22]. Due to many losses via runoff, leaching, ammonia volatilization, and denitrification, rice's nitrogen utilization efficiency (NUE) in field conditions can be as low as 25–34% (Brar *et al*., 2012) [3-4]. Rice output and quality are negatively impacted by the application of nitrogenous fertilizers, either in excess or below the ideal amount (Tyagi *et al*., 2022) [21].

When compared to the surface technique of irrigation, fertilization increases production, improves quality, and conserves water while using less fertilizer. With drip irrigation, the nitrogen utilization efficiency of aerobic rice was increased from 100% CPE to 175% CPE.

Growing rice with drip irrigation and fertigation is a recent concern. Therefore, dose needs to be standardized. Keeping the above facts in view, the present experiment was conducted to check the effect of NPK levels and drip irrigation levels on content and its uptake in rice grain and straw.

Materials and Methods

Experimental Site

The field experiment was conducted at G. B. Pant University of Agriculture and Technology, Pantnagar, district U. S. Nagar, Uttarakhand, during two consecutive kharif seasons in 2016 and 2017. The location of the study is in the Himalayan foothills range, at an altitude of 243.83 meters above mean sea level, at 29 N latitude and 79.5 E longitude.

Treatment details

In total, nine treatment combinations with three levels of each of two factors—nutrient levels (50, 75, and 100% of required NPK) and drip irrigation (50%, 75%, and 100% CPE)—were used in the experiment. The control, direct-seeded rice with flood irrigation, was reproduced three times.

Analysis

The analysis of data was done by Control vs Rest two stage method.

Chemical Analysis of Plants

At the harvest stage, rice plants' intake of nitrogen, phosphorus, and potassium was assessed in grain and straw. Plant samples were stored in drier at 70+ 20C till consistent weight after being sun dried for two to three days.

Dried plant samples were ground to fine powder and were analyzed for nitrogen, phosphorus and potassium (Jackson, 1973) [13]. Methods used for analysis of N, P and K in crop are given below:

Methods used for analysis of N, P and K in crop are given below

Elements	Method used
N	Modified micro kjeldahl method (Jackson, 1973) [13]
P	Vanado-molybdo phosphoric acid yellow color method using blue filter (Jackson, 1973) [13]
K	Flame photometry (Jackson, 1973) [13]

Using the dry matter of the crop plant and the N, P, and K content values, the nutrient absorption (kg/ha) by the rice crop was computed. The formula are given below.

$$\text{Nitrogen uptake by plant(kg/ ha)} = \frac{\text{N content (\%)in plant sample} \times \text{oven dry matter yield (kg/ ha)}}{100}$$

$$\text{Phosphorus uptake by plant(kg/ ha)} = \frac{\text{P content (\%)in plant sample} \times \text{oven dry matter yield (kg/ ha)}}{100}$$

$$\text{Potassium uptake by plant (kg/ ha)} = \frac{\text{K content (\%)in plant sample} \times \text{oven dry matter yield (kg/ ha)}}{100}$$

Results and Discussion

NPK content

The first year of the study had a larger nitrogen content in rice grains and straw than the second year, which may have been caused by the second year's higher rainfall, that increased the volume and weight density of the roots and improved N absorption. Grain and straw nitrogen contents varied greatly depending on irrigation and nitrogen levels in both years.

Nutrient dynamics critical to crop production were compellingly highlighted by examining the nitrogen (N), phosphorus (P), and potassium (K) content in grains and straw with respect to different drip irrigation levels and nitrogen-phosphorus-potassium (NPK) treatments. Perturbing trends are shown by analysing the percentage variations in nutritional content.

The nitrogen content of grains and straw showed an average rise of around 4.9% for grains and 4.7% for straw when crop evapotranspiration (CPE) was increased from 100% to 150% (Fig. 1 and Fig. 2). This significant increase indicates the significant influence of increased irrigation on promoting nitrogen absorption, which is probably due to increased moisture availability and increased nutrient uptake efficiency. On the other hand, the NPK level study showed an average increase of around 13.1% nitrogen content in grain and 12.6% in straw, moving from 50% to 100% of the suggested NPK (Fig.7 and Fig.8). This indicates a stronger reaction to optimal nutritional dosages in increasing nitrogen absorption in both grain and straw.

In 2016 and 2017, the nitrogen content of rice harvested using the drip technique (1.46% and 1.55%, respectively) was considerably greater than that of rice harvested using the flood method (by 22.7 and 19.2%, respectively). In comparison to the flood approach, drip irrigation produced directed seeded rice with a straw nitrogen content that was 3.7% and 8.3% higher in 2016 and 2017, respectively (Fig.13).

In terms of phosphorus content, the percentage changes in grain and straw with respect to drip irrigation levels showed a little average rise of around 8.3% and 7.7%, respectively, as irrigation intensified from 100% to 150% CPE (Fig.3 and Fig.4). These little variations point to a complex phosphorus uptake response to different watering rates. Analysing the effect of NPK levels also revealed a marginal average increase in straw when switching from 50% to 100% NPK (Fig.9 and Fig.10). This suggests that phosphorus absorption is moderately dependent on balanced NPK treatments in both grain and straw.

In direct seeded rice, the P content of the grain under the drip technique increased by 8.8 and 15.3% in 2016 and 2017, respectively, to a substantially higher level (0.37% in 2016 and 0.45% in 2017) than under the flood method. In comparison to the flood approach, the drip method of direct seeded rice achieved a considerably higher P content in the straw (0.15% in 2016 and 0.19% in 2017). The clear comparison is being depicted in Fig. 14.

Regarding potassium content, the percentage changes showed that increasing drip irrigation levels from 100% to 150% CPE resulted in an average increase of around 8.5% in grain and 9.1% in straw (Fig.5 and Fig.6). This little rise suggests a potassium absorption mechanism that is susceptible to increased watering techniques. On the other hand, when NPK treatments rose from 50% to 100%, the evaluation of NPK levels showed a discernible average rise of K content Fig. 11 and Fig. 12). This highlights the importance of balanced nutrient dosages in enhancing potassium absorption in both grain and straw.

By 28.9% in 2016 and 47.4% in 2017, the drip method of direct seeded rice achieved a much greater K content in the grain compared to the flood approach. The drip method and the flood method of drip irrigation showed notable differences in the K content of the rice straw. In comparison to the flood approach, the drip method recorded 18.7 and 16.6% considerably higher K content in rice straw in 2016 and 2017, respectively (1.52% in 2016 and 1.61% in 2017).

Furthermore, there are wider ramifications for sustainable agriculture from these findings. In addition to increasing crop yield, adjusting irrigation schedules and making the most of NPK applications also lowers the chance of fertiliser leakage into the environment, minimising pollution and resource waste.

To sum up, with the use of precision agriculture techniques and effective fertiliser management catered to the requirements of individual crops, agricultural systems may be made resilient and sustainable.

NPK uptake (kg/ha)

The N uptake by rice grain and straw varied significantly with irrigation and nutrient levels during both the years.150% CPE recorded significantly higher N uptake (59.65 kg/ha in 2016 and 73.59 kg/ha in 2017) than 100% CPE during 2016 and 2017, respectively. The rice straw uptake with 150% CPE was 30.76 and 42.7Kg/ha during 2016 and 2017 respectively. It was significantly higher than 100 and 125% CPE during both the years (Table 1). The N uptake in grain under 100% NPK was found significantly higher than 50% and 75% NPK. The 100% NPK level gained significantly higher nitrogen uptake by grain than 50 and 75% NPK levels. Drip method recorded higher N uptake in grain and straw than flood system. (Fig 15).

The phosphorus uptake by grain under 150% CPE was found significantly higher than 100 and 125% CPE in both the years. The phosphorus uptake by rice straw under 150% CPE was significantly higher (11.14 kg/ha in 2016 and 16.58 kg/ha in 2017) than 100 and 125% CPE. The 100% NPK levels recorded significantly higher P uptake by rice straw (11.20 kg/ha in 2016 and 16.63 kg/ha in 2017) over 50 and 75% levels of NPK (Table 1). P uptake under drip system was significantly higher in grain and straw during both the years (Fig 15).

The potassium uptake by rice straw and grains with 150% CPE was significantly higher (20.49 kg/ha in 2016 and 27.09 kg/ha in 2017) than 100% CPE during both the years. The 100% NPK level recorded significantly higher K uptake in grain and in straw than 50% NPK level. It was found significantly higher than 75% NPK in 2016 and remained statistically at par in 2017 (Table 1).

Drip method recorded 60.2 and 87.95% significantly higher K uptake by rice grain than flood method during 2016 and 2017, respectively with significantly higher K uptake by rice straw with an increase of 9.08 and 32.9 kg/ha during 2016 and 2017, respectively.

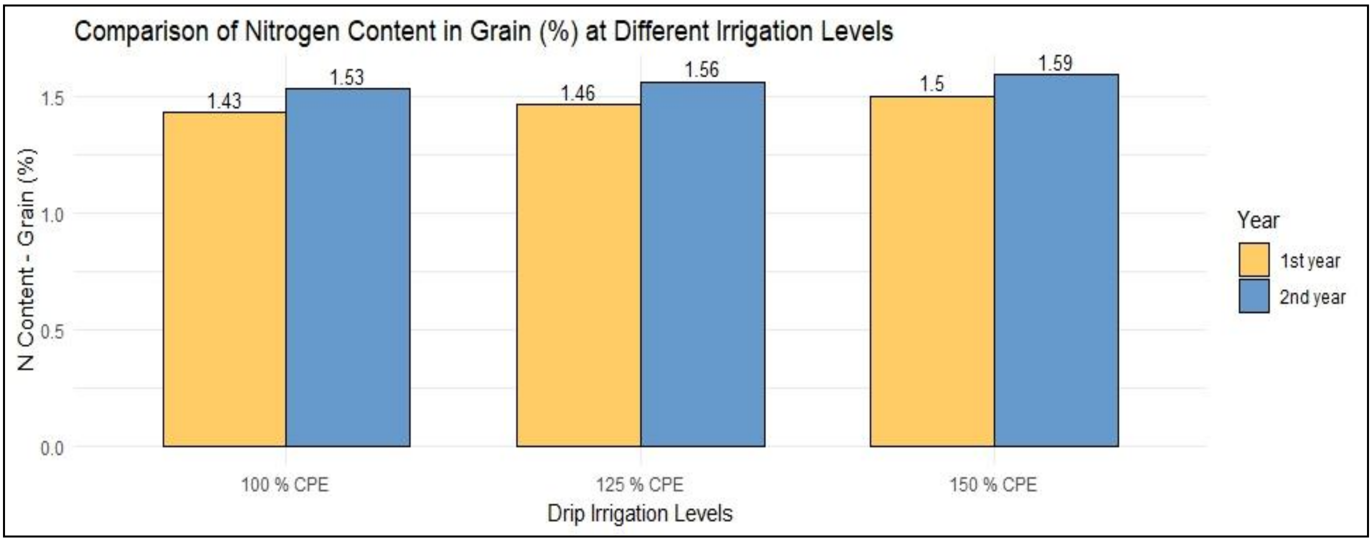

Fig 1: Comparison chart of N content in grain at different irrigation levels

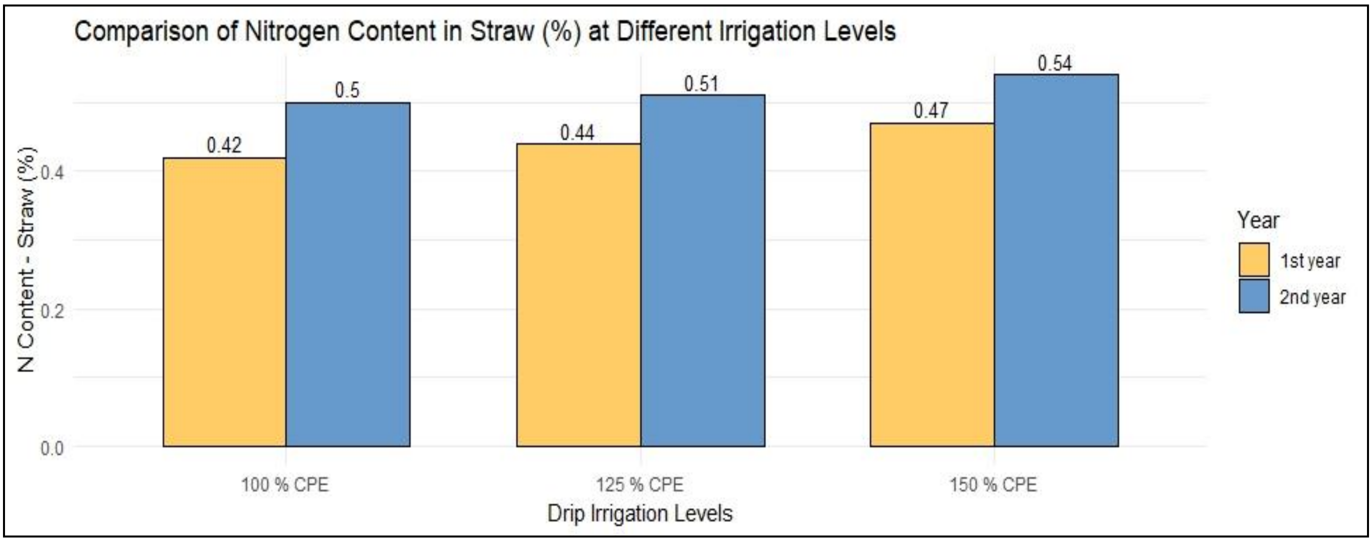

Fig 2: Comparison chart of N content in straw at different irrigation levels

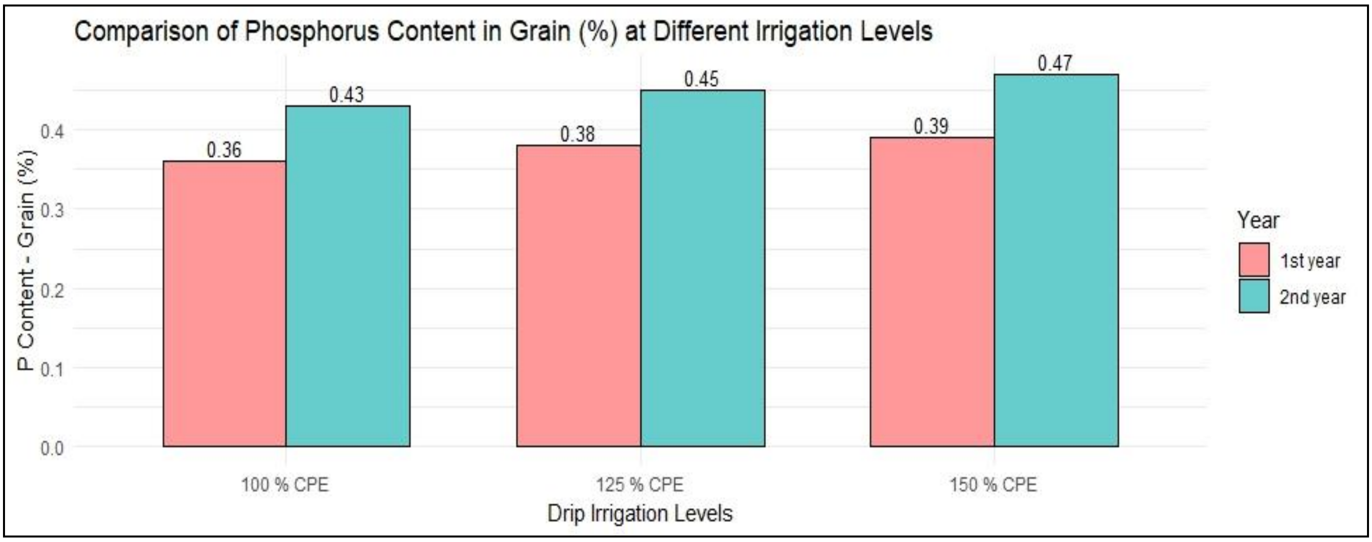

Fig 3: Comparison chart of P content in grain at different irrigation levels

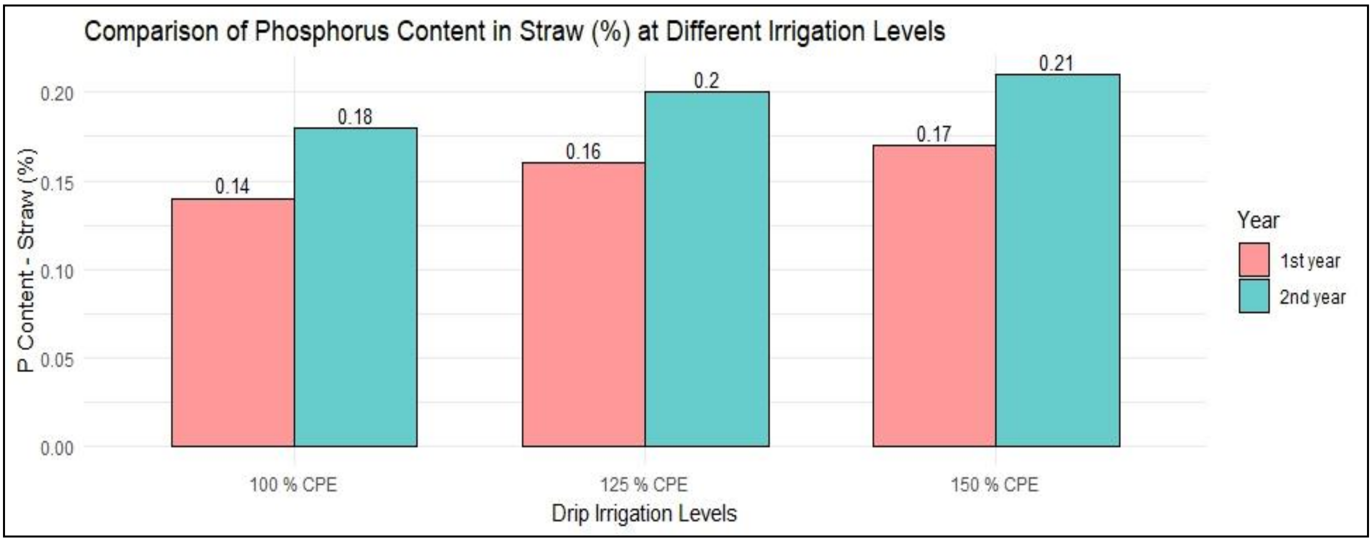

Fig 4: Comparison chart of P content in straw at different irrigation levels

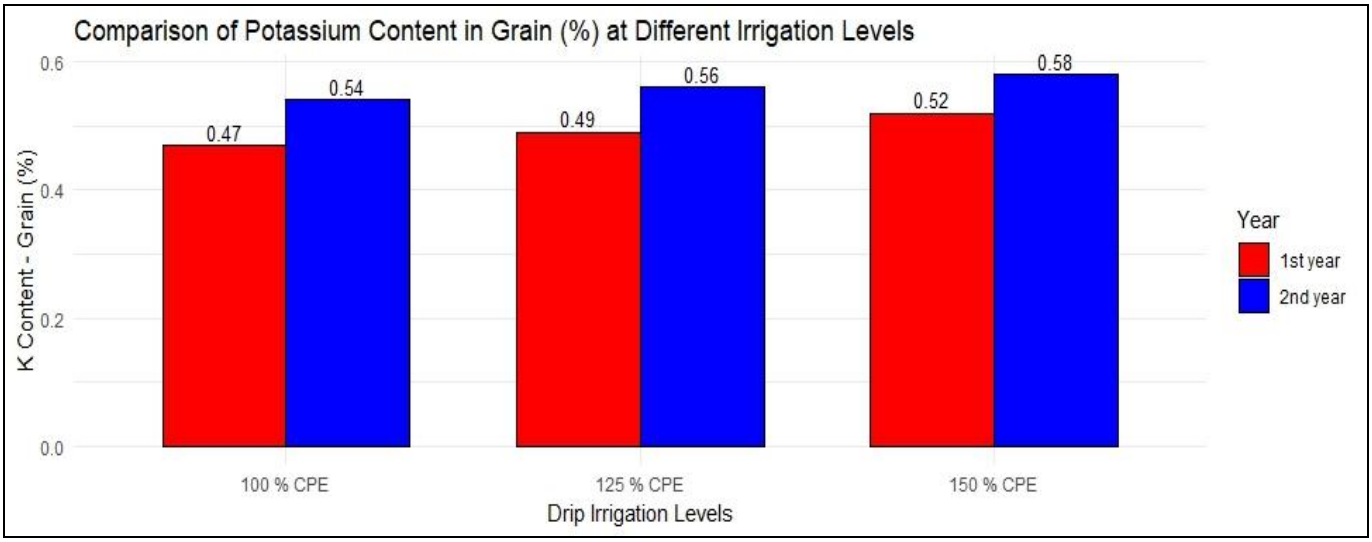

Fig 5: Comparison chart of K content in grain at different irrigation levels

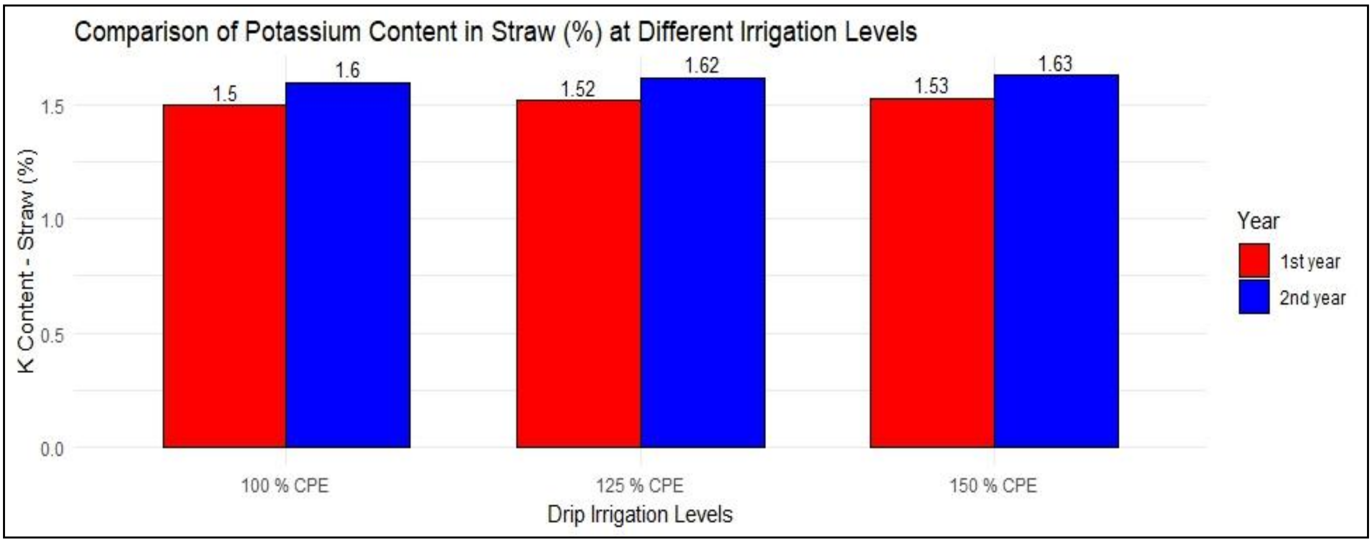

Fig 6: Comparison chart of K content in straw at different irrigation levels

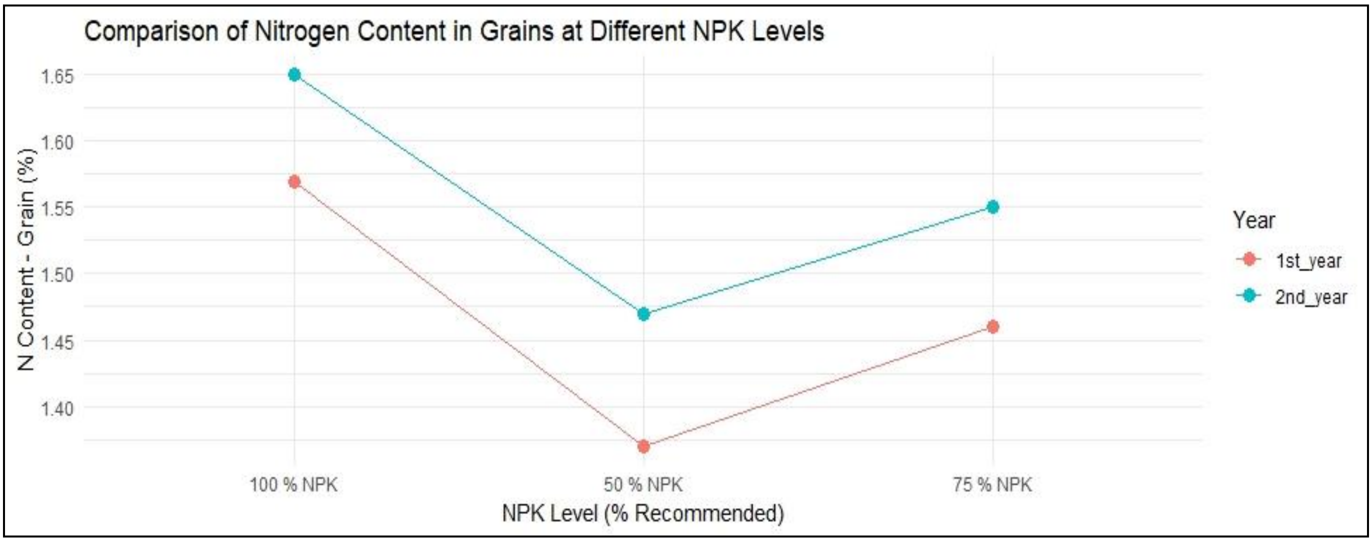

Fig 7: Comparison chart of N content in grain at different NPK levels

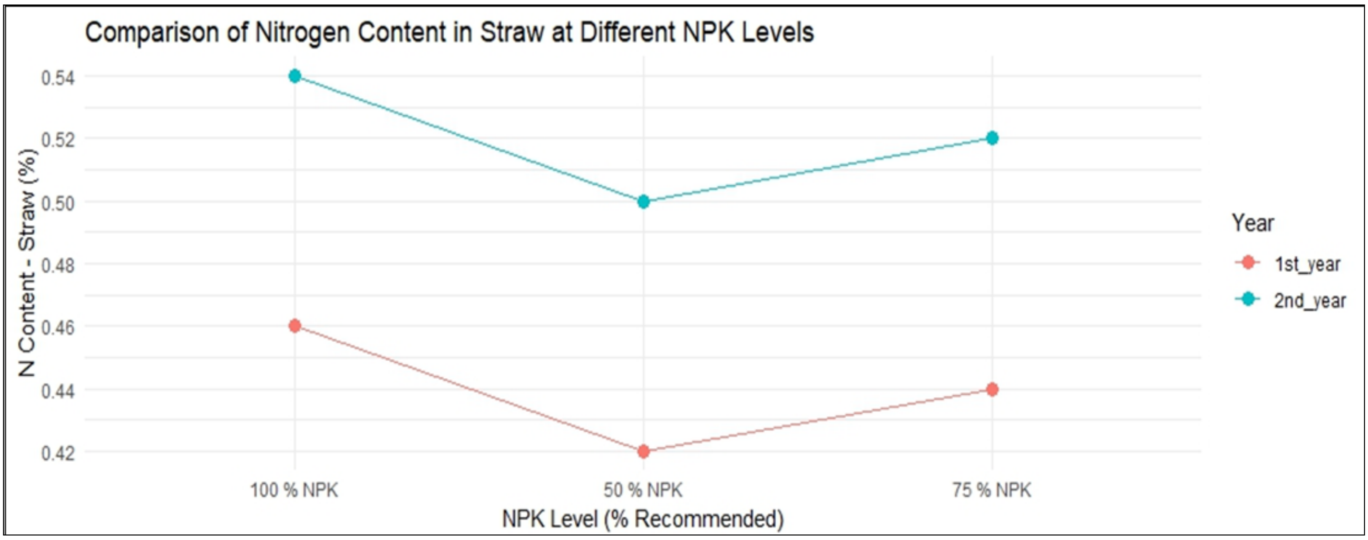

Fig 8: Comparison chart of N content in straw at different NPK levels

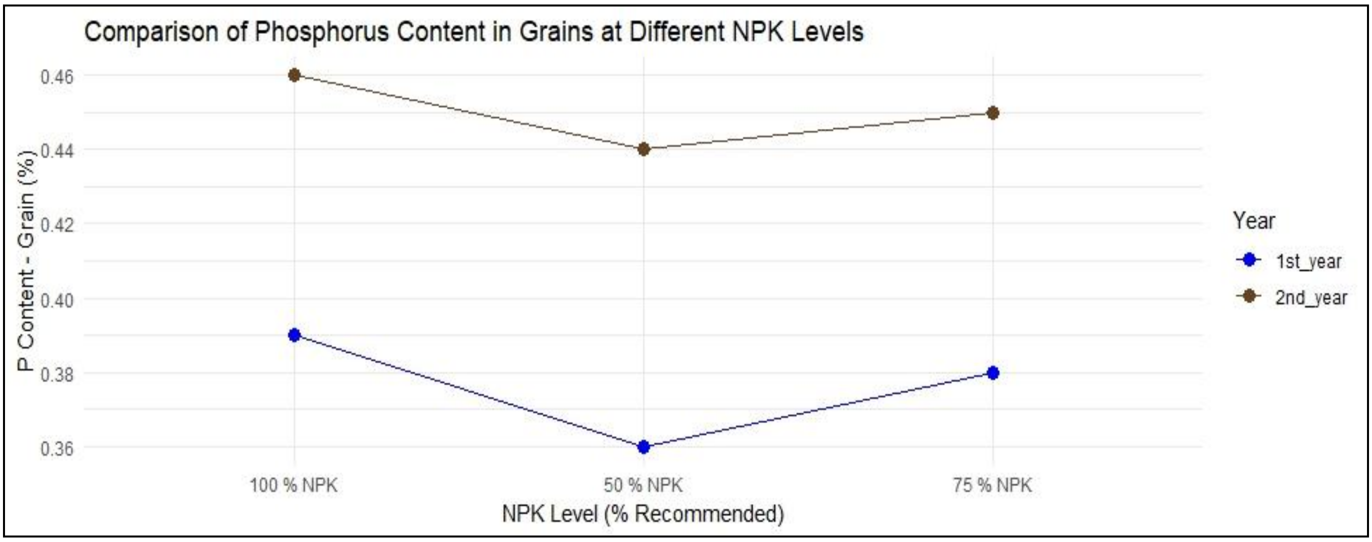

Fig 9: Comparison chart of P content in grain at different NPK levels

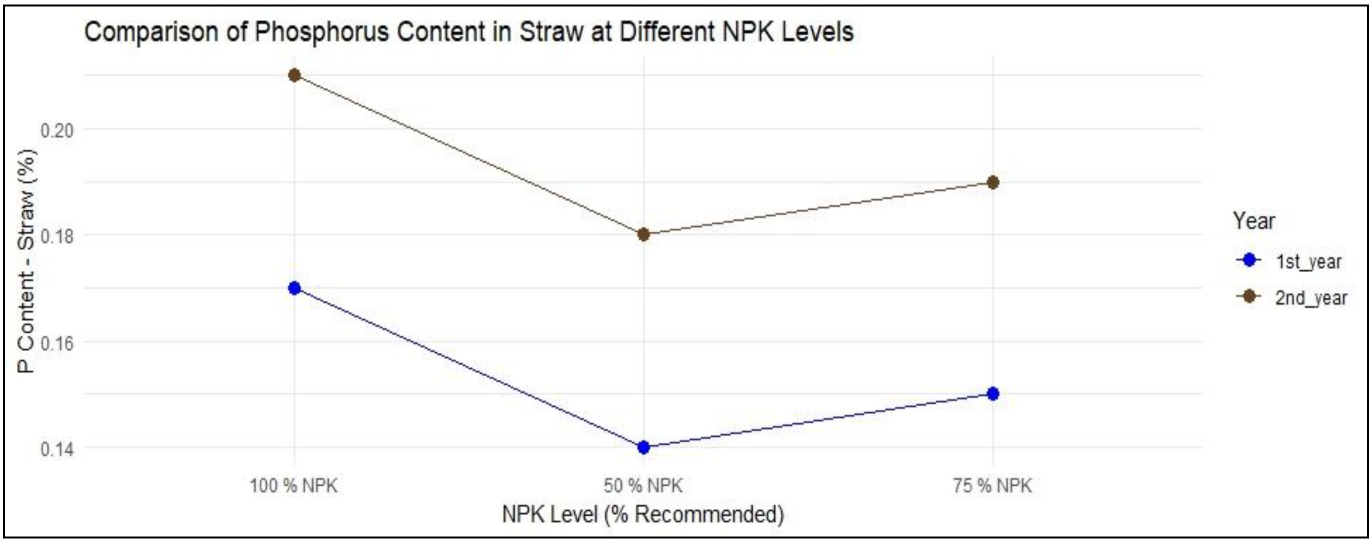

Fig 10: Comparison chart of P content in straw at different NPK levels

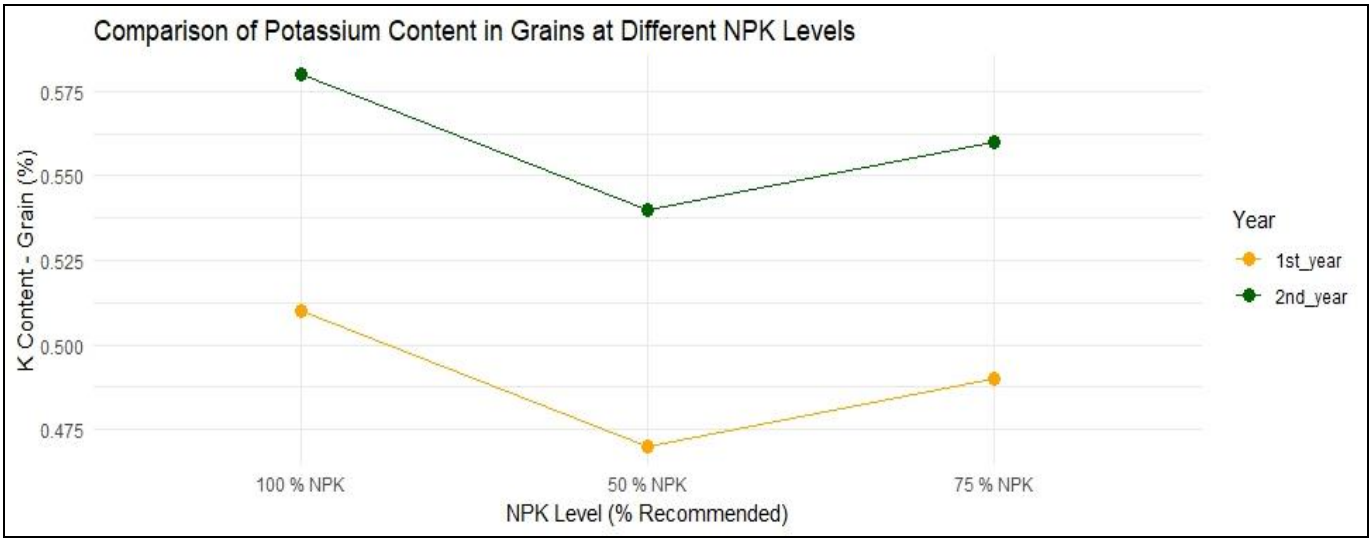

Fig 11: Comparison chart of K content in grain at different NPK levels

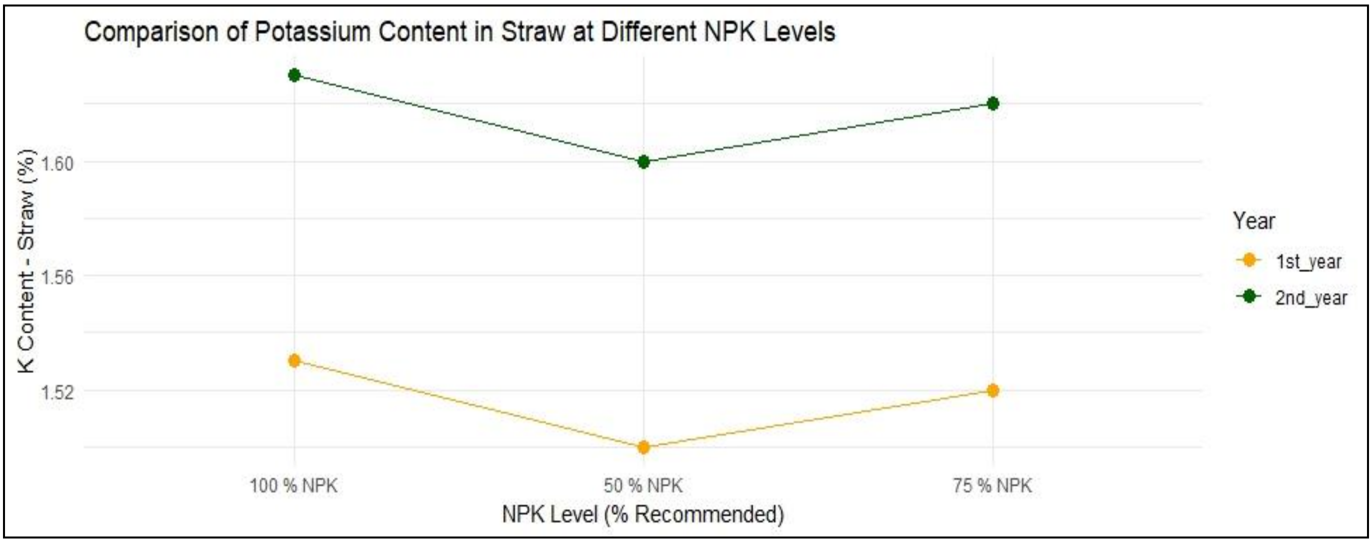

Fig 12: Comparison chart of K content in straw at different NPK levels

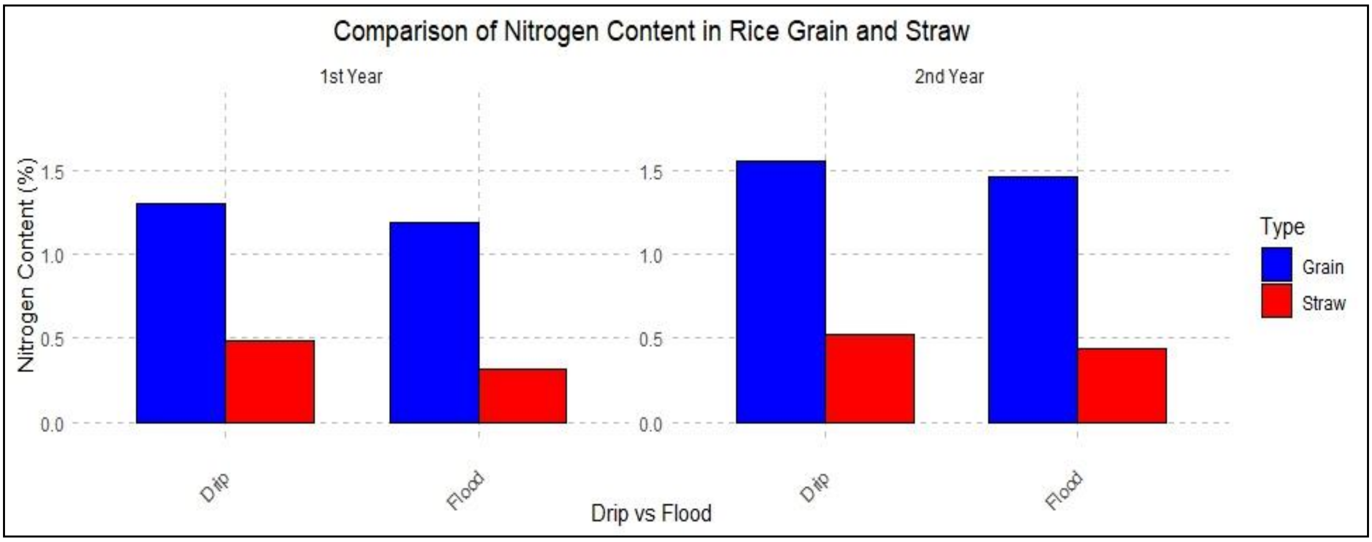

Fig 13: Comparison chart of N content in rice grain and straw between drip and flood method during two years

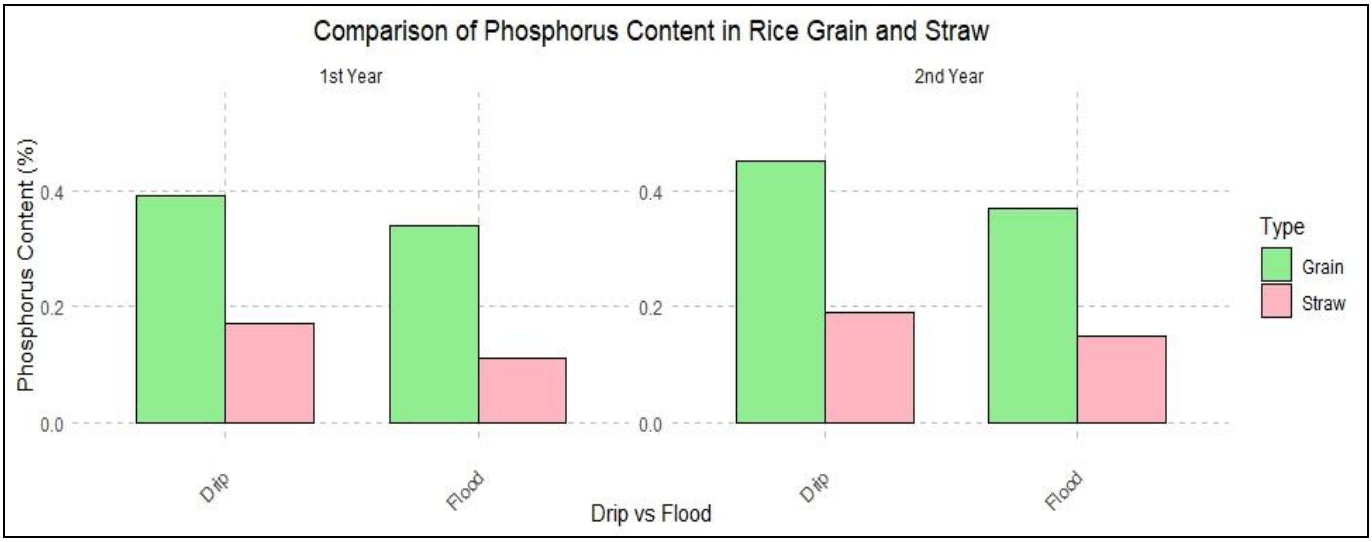

Fig 14: Comparison chart of P content in rice grain and straw between drip and flood method during two years

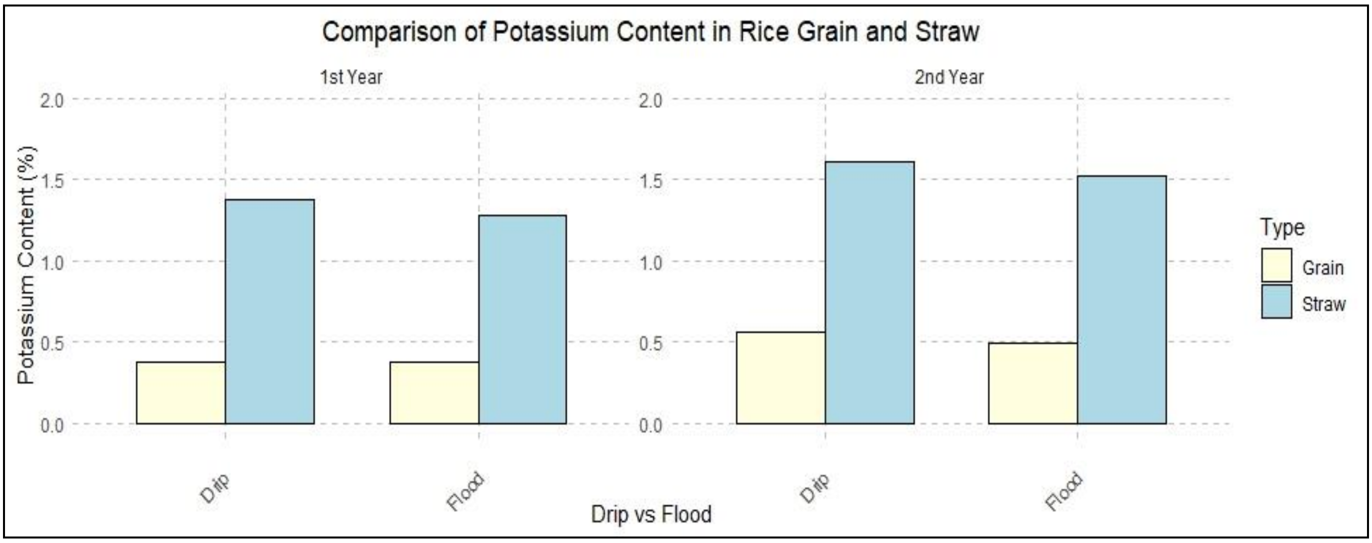

Fig 15: Comparison chart of K content in rice grain and straw between drip and flood method during two years

Table 1: NPK uptake (kg/ha) by rice grain and straw as affected by different treatments in 2016 and 2017

Treatment	N uptake (kg/ha)				P uptake (kg/ha)				K uptake (kg/ha)			
	Grain		Straw		Grain		Straw		Grain		Straw	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Drip irrigation level (% CPE)												
100	51.04	61.27	24.44	32.47	12.78	17.37	8.28	12.01	16.78	21.44	86.16	103.77
125	54.70	68.35	27.15	38.03	14.05	19.67	9.61	14.61	18.36	24.54	93.83	120.13
150	59.65	73.59	30.76	42.70	15.52	21.53	11.14	16.58	20.49	27.09	101.29	128.79
S.Em ±	1.53	2.41	0.91	1.04	0.38	0.60	0.44	0.52	0.50	0.86	2.90	3.03
CD (at 5%)	4.55	7.16	2.71	3.08	1.12	1.80	1.30	1.54	1.48	2.56	8.62	9.00
NPK level (% recommended)												
50	48.41	59.33	24.95	34.26	12.78	17.63	8.35	12.53	16.66	21.77	88.29	109.95
75	54.67	66.59	27.24	37.19	14.13	19.21	9.48	14.04	18.49	24.12	93.44	116.29
100	62.32	77.30	30.16	41.75	15.45	21.73	11.20	16.63	20.47	27.17	99.56	126.46
S.Em ±	1.53	2.41	0.91	1.04	0.38	0.60	0.44	0.52	0.50	0.86	2.90	3.03
CD (at 5%)	4.55	7.16	2.71	3.08	1.12	1.80	1.30	1.54	1.48	2.56	8.62	9.00
Control vs Rest												
DSR flood	36.23	44.21	21.17	29.56	10.35	17.11	7.28	10.52	11.57	12.96	84.68	84.61
Rest	55.13	67.74	22.45	37.71	14.12	19.52	9.67	14.4	18.54	24.35	93.76	117.6
S.Em ±	1.97	3.11	1.18	1.34	0.49	0.78	0.57	0.67	0.64	1.11	3.75	3.91
CD (at 5%)	5.87	9.24	3.50	3.97	1.45	2.32	1.68	1.99	1.91	3.31	11.13	11.61

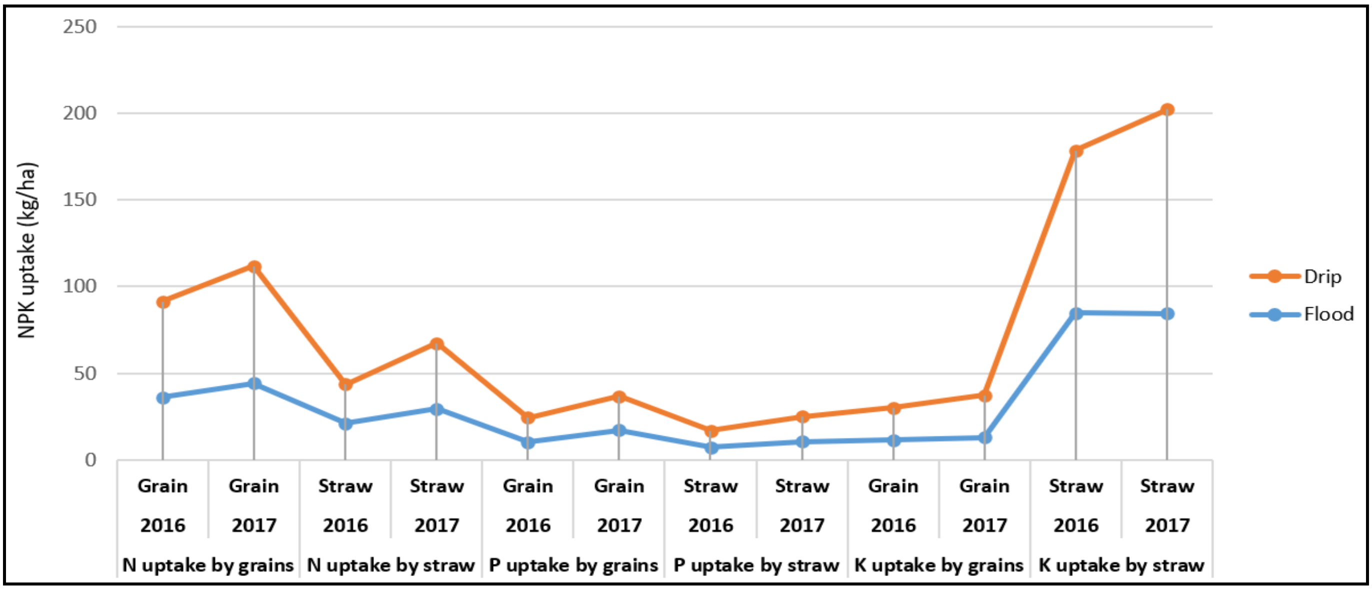

Fig 16: Drip vs Flood comparison in uptake by grains and straw during 2016 and 2017

Conclusion
Drip irrigation at 150% CPE recorded higher N, P and K uptake in grains and straw than other irrigation levels during both the years. The 100% NPK accumulated higher N, P and K uptake in grains and straw than 50 and 75% NPK levels during both the years. The flood method recorded lower N,P and K uptake by rice grains and straw during both the years.

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