***Original Research Article***

# Studies on Nutrient uptake, Nutrient use efficiencyand water productivity of Drip irrigated Ratoon Sugarcane as influenced by water soluble fertilizers

**Abstract:**

A field experiment was conducted at Zonal Agricultural Research Station, V.C. Farm, Mandya during 2020-21 to study the Nutrient content and Uptake of Drip irrigated Ratoon Sugarcane as influenced by water soluble fertilizers. The experimental site was red sandy loam soil with neutral pH, normal electrical conductivity, medium organic carbon, low available nitrogen, medium phosphorus and potassium content. The experiment was laid out in Randomized Complete Block Design with three replications comprising seven treatments with VCF-0517 sugarcane variety. The results revealed that application of 150 per cent RDF through WSF (325.9 kg $ha^{-1}$ N, 46.5 kg $ha^{-1}$ $P_2O_5$, 338.4 $K_2O$ kg $ha^{-1}$) recorded significantly higher nitrogen, phosphorus and potassium uptake compared to 100 per cent RDF through WSF (287.3 kg $ha^{-1}$ N, 37.5 kg $ha^{-1}$ $P_2O_5$, 282.6 kg $ha^{-1}$ $K_2O$) and 75 per cent RDF through WSF (269.9 kg $ha^{-1}$ N, 33.4 kg $ha^{-1}$ $P_2O_5$, 253.6 kg $ha^{-1}$ $K_2O$). Application of WSF at 75 per cent RDF resulted in greater NUE in case of nitrogen, phosphorus and potassium (348.3 kg $kg^{-1}$, 870.7 kg $kg^{-1}$ and 696.5 kg $kg^{-1}$ respectively) when compared with other fertigation levels and conventional fertilizer application.

**Keywords:** Fertigation, WSF (water soluble fertilizers), NUE (nutrient use efficiency)

## Introduction:

Around the world, sugarcane (*Saccharum officinarum* L.) is a lucrative economic crop. In addition to several byproducts, it is grown for the manufacture of sugar, fiber, biofuel, and manure. The crop is largely used for the production of sugar, gur and khandasari. The need for sweeteners is growing along with the population, so more effort is needed to cultivate and produce more sugarcane.The horizontal expansion of the area under the sugarcane crop in all probability is not possible due to stiff competition from food, fiber and oil seed crops, besides urbanization or industrialization with the growing population.

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Worldwide sugarcane production is constrained by a lack of water, land and labour as well as rising input costs. Water is, however, scarce for irrigation. The most important factor in its management is minimizing wasteful consumption as well as production costs and maintaining productivity (Qureshi and Afghan, 2005). To increase sugarcane production and productivity while using resources more effectively, farmers will need to employ cutting-edge technology like drip fertigation with water-soluble fertilizers.

In addition to boosting production, better irrigation water management with nutrient delivery is crucial for reducing the cost of cultivation of sugarcane in agriculture. By synchronizing nutrient supply with crop demand and reducing fertilizer use by up to 25–30 per cent, fertigation increases sugarcane production (Bhoi *et al*., 1999). Fertigation reduces groundwater contamination by reducing leaching of water and nutrients from the rhizosphere. Soluble fertilizers are consequently delivered directly to the feeding zone through irrigation systems by frequent application in lesser amounts. When handled properly, this offers useful alternatives for growing crops in environments that are similar to fertilizer solutions. The higher installation cost of the drip irrigation method is a significant impediment to its broad adoption. Altering the lateral spacing and switching to a paired row planting scheme, however, could lower the cost. Although there is a wide range of research on fertigation in sugarcane, the identification of location-specific optimum fertilizer levels in sugarcane under drip fertigation to increase use efficacy of fertilizer and researching on the effects of applying MAP (Mono Ammonium Phosphate), an acidic fertilizer, demand top priority. Such data are few, especially for the soils of Karnataka's southern dry zone, which is why the current study is being conducted.

**Material and Methods:**

The field experiment was conducted in D block of Zonal Agricultural Research Station, V.C. Farm, Mandya. The station is situated between 12°18’ and 13°04’ North latitude and 76°19’ and 77°20’ East longitude and at an altitude of 697 meters above mean sea level in southern dry zone (Zone–VI of NARP) of Karnataka which falls in southern dry zone (Region III) of India. Ratoon sugarcane was grown with seven treatments replicated thrice by adopting randomized complete block design. Treatment details follows like this

$T_1$: Control

$T_2$: RDF through CF + No FYM

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$T_3$: RDF through CF + FYM

$T_4$: 150% RDF through WSF + FYM

$T_5$: 125% RDF through WSF + FYM

$T_6$: 100% RDF through WSF + FYM

$T_7$: 75% RDF through WSF + FYM

NOTE: RDF: Recommended dose of fertilizer- 250:100:125 kg NPK $ha^{-1}$, CF-Conventional fertilizers (Urea, SSP and MOP); FYM - Farm yard manure (15 t $ha^{-1}$); WSF-Water soluble fertilizers (Urea, MAP, MOP).

Main crop was sowed during December 2018 and it was harvested during January 2020 from onwards crop kept for ratooning and harvested January 2021. The soil belongs *Alfisols* as per USDA classification. Composite soil samples were drawn from the experimental site during the growth stages and samples were air dried, powdered, sieved and analyzed for various physical and chemical properties.

Plant samples collected from each treatment separately, dried and powdered by using mixer grinder with stainless steel blade. The powdered samples were stored in airtight containers for further chemical analysis. These samples were used for N, P, and K estimation. Nitrogen was estimated with wet digestion and distillation adopting the procedure given by Jackson (1973). Phosphorus in plant samples was estimated upon digestion followed by colorimetric estimation using spectrophotometer adopting the procedure given by Jackson (1973). Total potassium of plant samples was estimated by flame photometry following the procedure given by Jackson (1973). Uptake of nitrogen, phosphorus and potassium were calculated using the following formula and expressed in kg $ha^{-1}$.

Nutrient uptake (kg $ha^{-1}$) = Nutrient content of cane (%) X Cane dry weight (t $ha^{-1}$) X 10

Nutrient use efficiency (NUE):Nutrient use efficiency was calculated by using the formula and expressed in kg $kg^{-1}$.

$$\mathrm{AE}(\mathrm{kg\ kg^{-1}}) = \frac{[\text{Grain yield in treated plot } (\mathrm{kg\ ha^{-1}}) - \text{Grain yield in control plot } (\mathrm{kg\ ha^{-1}})]}{\text{Fertilizer nutrient applied } (\mathrm{kg\ ha^{-1}})}$$

$$\mathrm{RE}(\mathrm{kg\ kg^{-1}}) = \frac{[\text{Nutrient uptake in treated plot } (\mathrm{kg\ ha^{-1}}) - \text{Nutrient uptake in control plot } (\mathrm{kg\ ha^{-1}})]}{\text{Fertilizer nutrient applied } (\mathrm{kg\ ha^{-1}})}$$

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**Results and Discussion:**

**Table 1: Influence of levels of water-soluble fertilizers through fertigation on nutrient uptake ratoon sugarcane at harvest**

| Treatments | N (kg ha$^{-1}$) | P (kg ha$^{-1}$) | K (kg ha$^{-1}$) |
|---|---|---|---|
| $T_1$: Control | 75.6 | 11.4 | 108.5 |
| $T_2$: RDF through conventional fertilizer +No FYM | 206.2 | 24.7 | 205.5 |
| $T_3$: RDF through conventional fertilizers + FYM | 221.7 | 27.8 | 218.1 |
| $T_4$: 150% RDF through water soluble fertilizers+ FYM | 325.9 | 46.5 | 338.4 |
| $T_5$: 125% RDF through water soluble fertilizers +FYM | 322.1 | 44.8 | 300.2 |
| $T_6$: 100% RDF through water soluble fertilizers +FYM | 287.3 | 37.5 | 282.6 |
| $T_7$: 75% RDF through water soluble fertilizers + FYM | 269.9 | 33.4 | 253.6 |
| **S.Em ±** | 8.73 | 2.72 | 5.17 |
| **CD ($p \leq 0.05$)** | 26.91 | 8.39 | 15.93 |

**Note: RDF:** Recommended Dosage of Fertilizer- 250:100:125 kg NPK ha$^{-1}$, **FYM:** Farm Yard Manure; Urea, SSP and MOP applied to soil in $T_2$ and $T_3$; Urea, MAP and MOP applied through drip in $T_4$ to $T_7$.

The data pertaining to total nutrient uptake as influenced by different levels of WSF of ratoon sugarcane are furnished in Table 1. Application of 150 per cent RDF through WSF (325.9 kg ha$^{-1}$) recorded significantly higher nitrogen uptake compared to 100 per cent RDF through WSF (287.3 kg ha$^{-1}$) and 75 per cent RDF through WSF (269.9 kg ha$^{-1}$), which is on par with 125 per cent RDF (322.1 kg ha$^{-1}$). Soil application of 100 per cent RDF through conventional fertilizers with FYM (221.7 kg ha$^{-1}$) and without FYM (206.2 kg ha$^{-1}$) exhibit significantly lower uptake of nitrogen compared WSF applied treatments. Soil application of 100 per cent RDF through conventional fertilizer with FYM (27.8 kg ha$^{-1}$) and without FYM (24.7 kg ha$^{-1}$) exhibit significantly lower uptake of phosphorus compared to WSF applied treatments except 75 per cent RDF through WSF (33.4 kg ha$^{-1}$). Application of 150 per cent

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RDF through WSF (46.5 kg $ha^{-1}$) recorded significantly higher phosphorus uptake compared to 100 per cent RDF through WSF (37.5 kg $ha^{-1}$) and 75 per cent RDF through WSF (33.4 kg $ha^{-1}$), which is on par with 125 per cent RDF (44.8 kg $ha^{-1}$). Higher potassium uptake was noticed with the application of 150 per cent RDF through WSF (338.4 kg $ha^{-1}$) compared to 125 per cent RDF (300.2 kg $ha^{-1}$), 100 per cent RDF through WSF (282.6 kg $ha^{-1}$) and 75 per cent RDF through WSF (253.6 kg $ha^{-1}$). Soil application of 100 per cent RDF through conventional fertilizers with FYM (218.1 kg $ha^{-1}$) and without FYM (205.5 kg $ha^{-1}$) exhibited significantly lower uptake of potassium compared to WSF applied treatments.

Generally, drip fertigation recorded higher availability of nutrients. The increased availability of nutrients might be due to split application of fertilizers up to nine months with different levels under drip fertigation system and intern resulted in reduction in loss of nutrients and availability of soil moisture. The split doses through drip enable in supply and solubilizing the nutrients near root zone, which favoured absorption and uptake of the plant nutrients by the crop. Similar findings were also reported by Shukla *et al.* (2007) and higher available NPK with drip fertigation was reported by Selvakumar (2006). Conventional fertilizer application of 100 per cent RDF with surface irrigation recorded lesser available nutrients. This could be due to the fact that soil applied nutrients were subjected to various losses through leaching, volatilization and surface runoff. A similar finding was also observed by Shobana (2002) and Aneg Singh *et al.* (2007) in sugarcane crop.

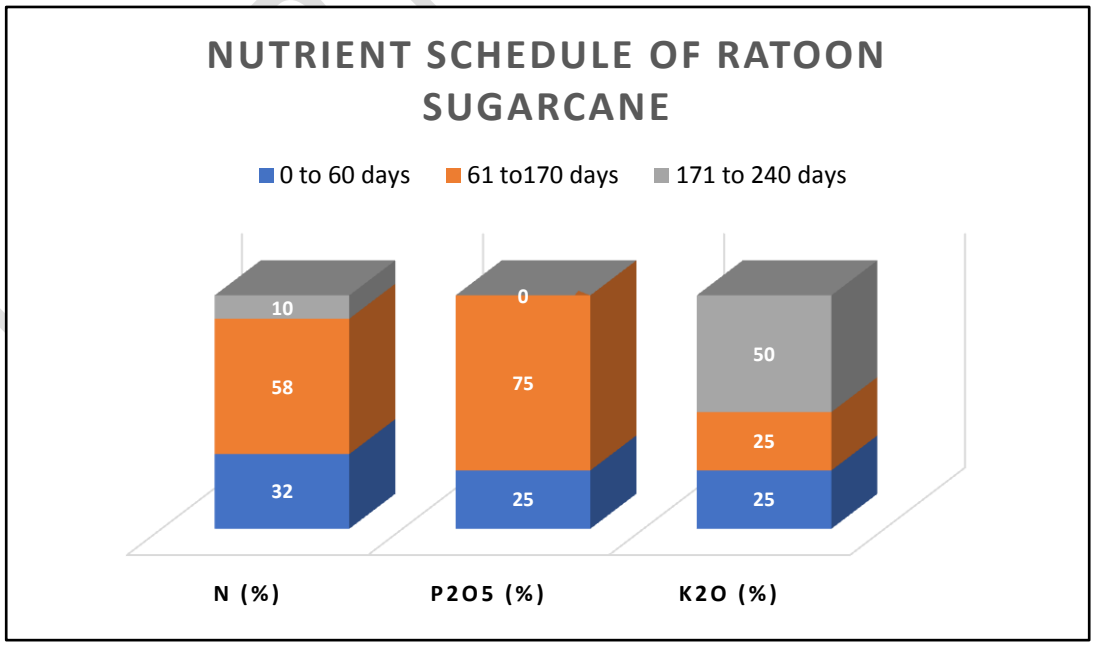
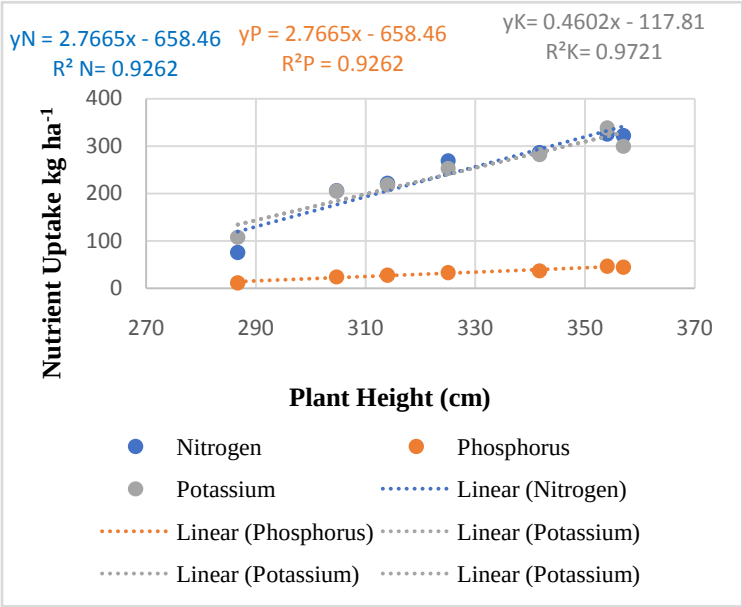
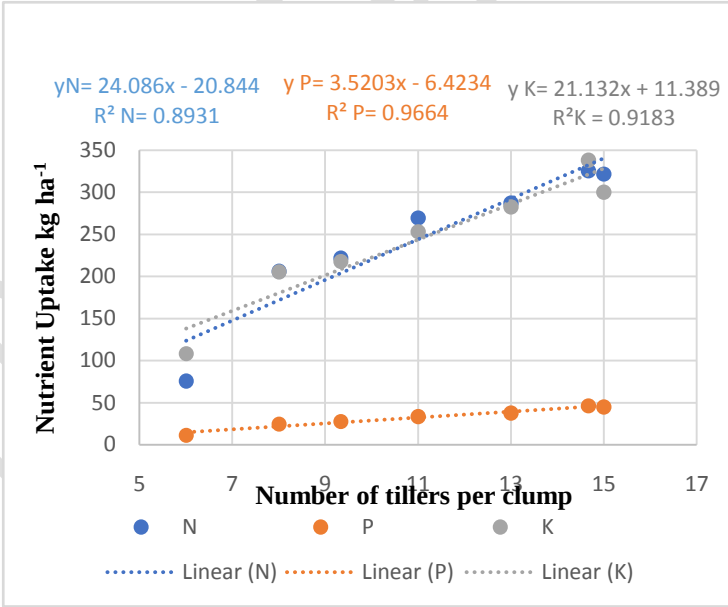



**Figure 1: Nutrient scheduling for sugarcane for fertigation**

In contrast to the soil application of urea, SSP and MOP, the application of water-soluble fertilisers (Urea, MAP, and MOP) delivered the nutrients during the crucial crop growth phases (Nutrients supplied according to fertilizer schedule as given in Figure 1) while synchronising with the demand and reaching nutrient absorption sites. In contrast to soil application of fertilizers where there is a broad range in nutrient availability, early strong growth of cane with the availability of the needed quantity of water and nutrients with WSF. According to Chaudhary (2019), favourable moisture availability under drip fertigation boosted nutrient uptake and supported good tiller formation.

(A) (B)




(C)

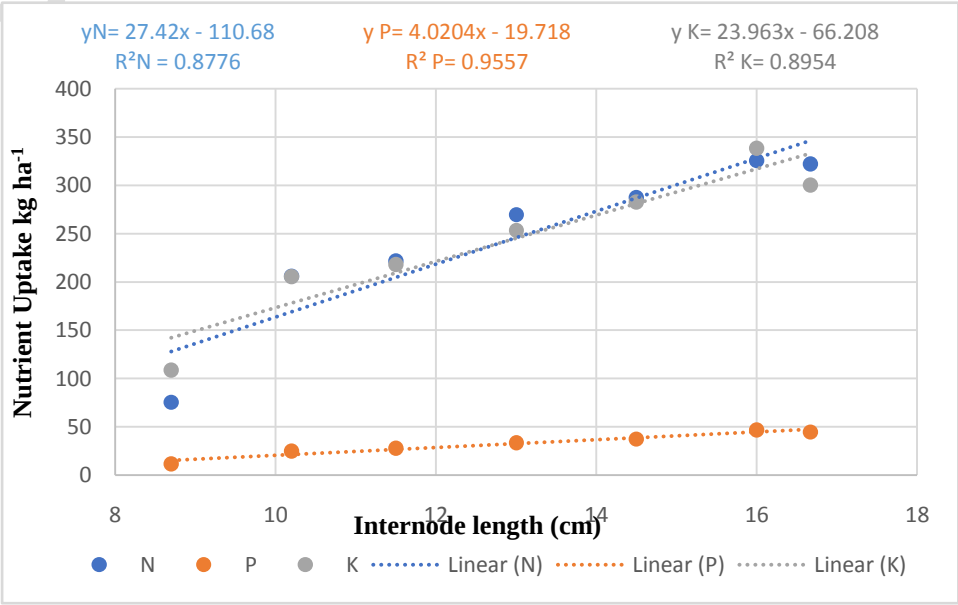



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**Figure 2: Study of correlation between Nutrient Uptake and Plant height (A), number of tillers per clump (B) and internodal length (C).**

The data on plant height (A), number of tillers per clump (B) and internodal length (C) recorded at harvest as influenced by conventional and water-soluble fertilizers were analyzed statistically and presented in Figure 2.A strong correlation was noticed with the uptake of N, P and K with Plant height, number of tillers and internode length. The plant heightat harvest with the application of 125 per cent RDF through WSF was significantly higher (357 cm) compared to 100 per cent RDF through WSF (341.7 cm) and 75 per cent RDF through WSF (325 cm), which is on par with 150 per cent RDF through WSF (354 cm). Soil application of 100 per cent RDF through conventional fertilizer with FYM (314 cm at harvest) and without FYM (304.7 cm at harvest), were significantly lower than WSF applied treatments.

Cane yield mainly depends on the number of millable canes and hence tillering is the principal component attributed towards achieving higher cane yield. Number of tillers clump$^{-1}$ at harvest with the application of 125 per cent RDF through WSF was significantly higher (15.0 clump$^{-1}$) compared 100 per cent RDF through WSF (13.0 clump$^{-1}$) and 75 per cent RDF through WSF (11.0 clump$^{-1}$), which is on par with 150 per cent RDF through WSF (14.67 clump$^{-1}$).Soil application of 100 per cent RDF through conventional fertilizer with FYM (9.33 clump$^{-1}$ at harvest, respectively) and without FYM (8.0clump$^{-1}$ at harvest) were significantly lower than WSF applied treatments.

Drip fertigation with different levels of WSF at harvest recorded significantly higher internodal length in $T_5$ treatment (16.67cm) compared to $T_6$ (14.50 cm) and $T_7$ treatment (13.0 cm), which is on par with $T_4$ treatment (16.0 cm). Whereas significantly lower internodal length was recorded in conventional fertilizer soil-based application with FYM (11.50 cm) and without FYM (10.20 cm) compared to WSF applied treatments.

Application of WSF at 150, 125, 100 and 75 per cent of RDF through drip recorded significantly higher growth parameters viz., plant height, number of tillers and internodal length compared to soil application of conventional fertilizers at 100 per cent RDF with or without FYM. The results also indicated that application of WSF at 75 per cent RDF through drip affects the growth parameters significantly higher compared to the soil application of conventional fertilizers at 100 per cent RDF with or without FYM, thus application of WSF at 75 per cent of RDF through drip resulted in not only saving 25 per cent RDF which aims at

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better water and nutrient supply to the root zone and their by achieving higher growth attributes reported by Mahendran and Dhanalakshmi (2003) in sugarcane.

Higher plant height, number of tillers and internodal length were observed in 125 per cent RDF through drip, but beyond 125 per cent RDF through drip there was slight reduction in the growth parameters indicating law of diminishing marginal returns as indicated by Alfred Marshal. The results also agreed with the findings of Nadagouda (2011) in sugarcane. The increase in plant height, number of tillers and internodal length can be attributed to incremental supply of (WSF - Urea, MAP and MOP for a period of 6 months & Urea and MOP up to 9 months) nutrients throughout the crop growth compared to soil application indicating timely and continuous supply of nutrients to the root zone for better growth and development.

The plant height increased with increase in levels of drip fertigation might be due to continuous accessibility of nutrients and moisture near the rhizosphere and also due to increased root proliferation with better utilization of nutrients. The better availability of nutrients at critical stages of crop growth phase resulted in greater plant height which helps for cell differentiation and cell metabolism in successive stages. The similar observations were noticed by Aujla et al. (2005) in Sugarcane.

Generally, tillering was higher in all the drip fertigation treatments compared to soil application of conventional fertilizers. The application of water-soluble fertilizers (Urea, MAP and MOP) supplies the nutrients during the critical crop growth stages synchronizes the demand and supply in available form compared to soil application of urea, SSP and MOP in splits. Results in early vigorous growth of cane with the availability of required quantity of water and nutrients at the early stages compared to soil application of fertilizers wherein the fluctuation in nutrient availability is very wide (Gouthaman, 2010). Favourable moisture availability under drip fertigation enhanced the nutrient uptake and favoured for good tiller production by Chandrashekar (2009).

The supply of 125 per cent RDF through WSF resulted in thick and longer internodes which can be attributed to timely supply of adequate nutrients and moisture leading to greater photosynthetic mobility and transportation of photosynthates intern resulted in rapid cell division and cell elongation (Veeraputhiran et al., 2002).

**Table 2: Influence of levels of water-soluble fertilizers through fertigation on agronomic efficiency and water productivity (t ha-cm$^{-1}$) of ratoon sugarcane**

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| Treatments | N | P | K | Water productivity (t ha-cm$^{-1}$) |
|---|---|---|---|---|
| | kg kg$^{-1}$ | | | |
| $T_1$: Control | - | - | - | 0.54 |
| $T_2$:RDF through conventional fertilizer +No FYM | 187.8 | 469.6 | 375.7 | 0.73 |
| $T_3$:RDF through conventional fertilizers + FYM | 217.5 | 543.8 | 435.0 | 0.86 |
| $T_4$: 150% RDF through water soluble fertilizers+ FYM | 233.5 | 583.7 | 466.9 | 1.06 |
| $T_5$: 125% RDF through water soluble fertilizers +FYM | 289.0 | 722.4 | 577.9 | 1.08 |
| $T_6$: 100% RDF through water soluble fertilizers +FYM | 303.5 | 758.8 | 607.0 | 0.99 |
| $T_7$: 75% RDF through water soluble fertilizers + FYM | 348.3 | 870.7 | 696.5 | 0.93 |
| **S.Em ±** | NA | NA | NA | 0.04 |
| **CD ($p$≤0.05)** | | | | 0.12 |

**Note: RDF:** Recommended Dosage of Fertilizer- 250:100:125 kg NPK ha$^{-1}$, **FYM:** Farm Yard Manure, NA: Not Analyzed Urea, SSP and MOP applied to soil in $T_2$ and $T_3$; Urea, MAP and MOP applied through drip in $T_4$ to $T_7$.

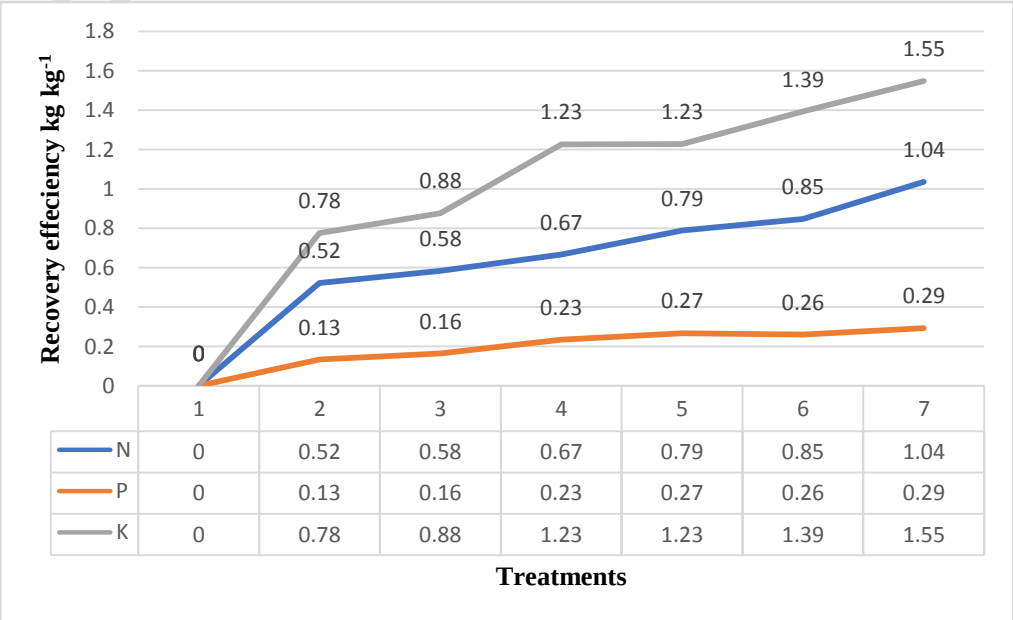


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**Figure 3: Influence of levels of water-soluble fertilizers through fertigation on Recovery efficiency of N, P and K.**

Based on the amount of nutrients applied and its corresponding yield, Agronomic use efficiency is worked out for N, P and K and observed variation due to different levels of WSF are furnished in Table 2. Application of WSF at 75 per cent RDF resulted in greater NUE in case of nitrogen (348.3 kg $kg^{-1}$) when compared with other fertigation levels (T4-233.5, T5-289.0, T6- 303.5 kg $kg^{-1}$, respectively) and conventional fertilizer application (T2-187.8 kg $kg^{-1}$, T3-217.5 kg $kg^{-1}$). Nutrient use efficiency was higher in case of phosphorus with application of WSF at 75 per cent RDF (870.7 kg $kg^{-1}$) when compared with other fertigation levels (T4-583.7, T5-720.7, T6-758.8 kg $kg^{-1}$, respectively) and soil application (T2-469.6 kg $kg^{-1}$, T3-543.8 kg $kg^{-1}$). Nutrient use efficiency was greater in case of potassium with application of WSF at 75 per cent RDF (696.5 kg $kg^{-1}$) when compared with other fertigation levels (T4-466.9, T5-577.9, T6-607.0 kg $kg^{-1}$, respectively) and soil application (T2-375.7 kg $kg^{-1}$, T3-435.0 kg $kg^{-1}$).

Recovery efficiency is worked out for N, P and K (Figure 3) and observed variation due to different levels of WSF. Application of WSF at 75 per cent RDF resulted in greater RE in case of nitrogen (1.04 kg $kg^{-1}$) when compared with other fertigation levels (T4-0.67, T5-0.79, T6- 0.85 kg $kg^{-1}$, respectively) and conventional fertilizer application (T2-0.52 kg $kg^{-1}$, T3-0.58 kg $kg^{-1}$). Recovery efficiency of phosphorus with application of WSF at 75 per cent RDF (0.29 kg $kg^{-1}$) when compared with other fertigation levels (T4-0.23, T5-0.27, T6-0.26 kg $kg^{-1}$, respectively) and soil application (T2-0.13 kg $kg^{-1}$, T3-0.16 kg $kg^{-1}$).REK (Recovery efficiency of potassium) was greater with application of WSF at 75 per cent RDF (1.55 kg $kg^{-1}$) when compared with other fertigation levels (T4-1.23, T5-1.23, T6-1.39 kg $kg^{-1}$, respectively) and soil application (T2-0.78 kg $kg^{-1}$, T3-0.88 kg $kg^{-1}$).

Efficient use of fertilizers is necessary for optimum growth and yield of ratoon sugarcane. Application of WSF through drip to the active root zone resulted in decreased loss of nutrients and their by enhancing the use efficiency. The findings are in line with the results Veeraputhiran (2000), Aujla *et al.* (2005) and Subramani (2008). They reported higher nutrient use efficiency under drip fertigation compared to soil application of fertilizer. Plant nutrient availability in the soil is very important factor for exploiting higher cane production. Leaching of nutrients, volatilization of fertilizers and fixation of nutrients in the soil are some of the factors that affect the availability of nutrients. Similar results were also reported by

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(Debashis Chakraborty *et al*., 1999).

Water productivity (t ha-cm$^{-1}$) represented in the Table 2 shows that Application of 125 % RDF through WSF (1.08 t ha-cm$^{-1}$) found statistically on par with 150 % RDF (1.06 t ha- cm$^{-1}$) and 100 % RDF (0.99 t ha-cm$^{-1}$). However, due to lower cane yield, the least WUE was noticed with control (0.54 t ha-cm$^{-1}$). In addition, application of WSF at 75 % RDF registered significantly greater water productivity (0.93 t ha-cm$^{-1}$) when compared with soil application of conventional fertilizer without FYM (0.73 t ha-cm$^{-1}$), which is on par with soil application of conventional fertilizer with FYM (0.86 t ha-cm$^{-1}$). Water use efficiency of cane increased by 26 per cent in drip fertigation system, when same quantity of water was applied as compared to surface irrigation (Aujla *et al*., 2005). The minimum loss of water resulted in the lower water requirement in drip fertigation system compared to surface irrigation (Sankar *et al.*, 2008). Effective utilization of available water supplied at regular intervals throughout the crop period to meet out the crop demand increases the water productivity under drip fertigation system.

**Conclusion:**

Application of 150 per cent RDF through WSF recorded significantly higher nitrogen (325.9 kg ha$^{-1}$), phosphorus (46.5 kg ha$^{-1}$) and potassium (338.4 kg ha$^{-1}$) uptake compared to conventional fertilizer soil-based application and NUE found to be higher withapplication of 75 per cent of RDF through WSF,noticed greater nutrient use efficiency of nitrogen (348.3kg kg$^{-1}$), phosphorus (870.7kg kg$^{-1}$) and potassium (696.5 kg kg$^{-1}$) when compared with other fertigation levels and soil application of conventional fertilizers. Application of WSF at 125 per cent RDF noticed significantly greater WUE (1.08 t ha-cm$^{-1}$) compared to conventional fertilizer soil-based application with FYM (0.86 t ha-cm$^{-1}$) and without FYM (0.73 t ha-cm$^{-1}$), which is on par with 150 per cent RDF (1.06 t ha-cm$^{-1}$) and 100 per cent RDF (0.99 t ha-cm$^{-1}$) through WSF.

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