

Original Research Article

Macronutrient Status and Soil Chemical Properties as Influenced by Methods and Schedule of Fertilizer Application Under Widely Spaced Sugarcane Crop (*Saccharum officinarum* L.) in Alfisols of Karnal District, Haryana

1. Abstract:

An experiment was conducted at Regional Research Station, Uchani (Karnal) of CCS Haryana Agricultural University, Hisar, India to assess the effect of method and schedule of fertilizer application on macronutrient status *viz.* available Nitrogen (N), Phosphorus (P) and potassium (K) and soil chemical properties *i.e.* soil pH, electrical conductivity (EC) and soil organic carbon (SOC) at different intervals of crop growth period. The experiment was laid out in split plot design with two methods of fertilizer application (B1-broadcasting and B2-band placement) as main plot treatments and four sub plot treatments consisting of application of recommended dose of N and K fertilizer (RDF) in different number of splits at different no. of days after planting (DAP) *i.e.* T1(five splits), T2(six splits), T3(seven splits) and T4(three splits). Results elucidated that availability of all the macronutrients was significantly affected by both sub and main plot treatments at different stages of crop growth period. Available N content was found to be significantly higher in B2 compared to B1 at all the time intervals from 75 DAP (131.86 Kg ha⁻¹) to harvest (145.91 Kg ha⁻¹) reaching the maximum at 180 DAP (142.80 Kg ha⁻¹). Among the sub plot treatments, T4 and T1 respectively reported significantly higher values of available N from 75 DAP (134.51 Kg ha⁻¹) to 90 DAP (147.08 Kg ha⁻¹) and 90 DAP (153.10 Kg ha⁻¹) to 150 DAP (162.11 Kg ha⁻¹). At 180 DAP and at the time of harvesting, significantly higher values of available N (159.21 Kg ha⁻¹ and 157.01 Kg ha⁻¹) were observed in treatments receiving fertilizer in T2 and T3 splits respectively. Available K content was significantly higher in B1 compared to B2 at all the time intervals except at 0, 150, 180 DAP and at harvest where the difference was not significant. Higher values of available K were reported under T4 upto 75 DAP (225.30 Kg ha⁻¹) and thereafter, T1 exhibited significantly higher available K values upto 150 DAP (222.06 Kg ha⁻¹). At 180 DAP and at the time of harvesting, significantly higher values of available K (225.10 Kg ha⁻¹ 227.48 Kg ha⁻¹) were observed T2 and T3 respectively. Available P content was significantly higher (24.63 Kg ha⁻¹) in B1 compared to B2 at the time of harvesting. Soil pH, EC and SOC did not registered any significant change under any treatment.

Key words: Split application, Band Placement, Broadcasting, Fertilizer application, Nitrogen, Potassium

2. Introduction:

Chemical fertilizers are the most crucial inputs to satisfy nutrient requirement of crops for obtaining high yield in modern crop production. Modern agriculture is extensively dependent upon fertilizers and they are regarded as vital tools for global food safety (Pahalvi *et al.*, 2021). Price of fertilizers which are already expensive keep on increasing due to a gap in demand and supply of fertilizer minerals (Randive *et al.*, 2021) which directly adds up a significant portion to the cost of cultivation. Therefore, reduction in cost of cultivation demands adoption of effective nutrient management techniques. The employment of fertilizers also influences soil physicochemical and biological properties (Singh *et al.*, 2019). The imbalanced use or inefficient management of chemical fertilizers may reduce soil fertility and can cause soil, water and air pollution along with a reduction in important nutrients of soil and minerals when applied without following standard agronomic practices (Katyal and Chaudhri, 2021). To avoid these harmful effects, innovative approaches like 4R nutrient stewardship approach may serve as a guide for the effective nutrient management. The concept of this approach emphasizes the application of right source of nutrient at right rate and time and in the right place (Fixen, 2020).

The adoption of the proper method of fertilizer application is essential to minimize the loss of nutrients from the soil with simultaneous rise in its availability and it is equally important at the time of application to achieve higher nutrient use efficiency. Method and time of fertilizer application are important components of an effective nutrient management programme. Band placement of nitrogenous fertilizer in subsurface portion of soil prevents its loss through volatilization. Nitrogen is mobile in soil whereas fixation of P and K occurs in soil suggesting their placement in bands along the crop rows to make them easily available (Shukla *et al.*, 2018). Band Placement of potassium is recommended in soils having low level of K or with a high K fixing capacity. In upland areas, several studies indicates band placement overwhelmingly superior than broadcasting as long as efficiency is concerned. Proper placement carries the same gravity in P management under wide row spacing as split application carries for N management. P and K applied through fertilizers tend to fix into the soil, therefore practicing band placement aids in reducing fixation and increases their availability (Farmaha *et al.*, 2013 and Fernández and White, 2012) Band placement of fertilizer near root zone aids the roots to easily draw nutrients from soil as it minimize the distance between root hairs and nutrients placed in soil. Less contact with the soil lessens the opportunity for nutrient loss due to leaching or fixation reactions. Placement decisions depend on the crop and soil conditions, which interact to influence nutrient uptake and availability (Roberts,2008).

Nitrogen fertilizers are expensive and crops are able to utilize only 50% of nitrogen provided by them. Suitable fertilizers application strategies which makes some amount of added fertilizer, available for early growth and left over part in later growth stages of crop should be encouraged (Pandey *et al.*,

2019). Precision nutrient application by splitting the recommended dose of fertilizer may be functional in improving sustainability of available N by preventing leaching or volatilization losses of fertilizers (Allen *et al.*, 2010). Split application refers to application of total dose of fertilizer in fragments for synchronization of supply of applied nutrient with the need of plant as well as ability of plants to use these nutrients. If full dose of nutrients especially N is applied in a single dose as pre planting or at planting, the window for the potential loss of these nutrients is through various pathways is always open. By postponing a portion of N treatment until the crop is better able to utilize the nutrient, plants take up the nitrogen more quickly and efficiently. Fixation of K in soil can be minimized by its split application which facilitates enhanced access and use efficiency by plant (Romheld and Kirkby, 2010).

3. Materials and Methodology:

3.1. Experimental Site and Climate

Field experiment was conducted at Regional Research Station, CCS Haryana Agricultural University, Karnal located at latitude of 29°43'42.19" N and longitude of 76°58'49.88" E and at an altitude of 253 meters above mean sea level. It is roughly equidistant and almost midway from New Delhi and Chandigarh.

The climate is sub-tropical with mean maximum temperature ranging between 34-39 °C in summer and mean minimum temperature ranging between 6-7 °C in winter. Most of the rainfall is received during the months of July to September and few showers during December to late spring.

3.2 Soil of Experimental Plot

The field at Regional Research Station, CCSHAU, Karnal selected for conducting the experiment was uniform in fertility gradient. Initial soil fertility status of experimental field was determined prior to planting of crop, for which four representative soil samples were collected randomly from the entire field at a depth of 0-30 cm before implementing the final layout of experiment. The analysis was carried out by strictly following established protocols and standard procedures. From the interpretation of results obtained after soil analysis, it was interpreted that soil exhibited clay loam texture, alkaline in reaction, medium in OC content , low in available N and medium in P and K content.

Table 1: Initial physio-chemical properties of the soil under experiment

S. No.	Parameter	Value/ Category	Analytical Method Used
1.	Soil Texture	Clay loam	International pipette method (Piper,1966)
2.	pH _(1:2)	8.28	pH was determined using digital pH meter

3.	EC _(1:2) (dS m ⁻¹)	0.25	EC was determined using digital EC meter
4.	OC (%)	0.48	Wet digestion method (Walkley and Black, 1934)
5.	Av. N (kg ha ⁻¹)	111.55	Alkaline Potassium Permanganate Method (Subbiah and Asija, 1956)
6.	Av. P (kg ha ⁻¹)	18.88	Sodium Bicarbonate Extractable P method (Olsen <i>et al.</i> , 1954)
7.	Av. K (kg ha ⁻¹)	201.40	Ammonium Acetate Extractable K method (Jackson, 1973)

3.3 Treatments and Layout of the Experiment:

The experiment was arranged in Split Plot Design with three replications. The experiment was designed with two main plots (Mode of fertilizer application i.e. Broadcasting and Band Placement) and four sub-plots (No. of split application i.e. 5, 6, 7 and 3 splits). The details of experiment are given below:

3.4 Treatment Details:

3.4.1 Main plot treatments (two): Methods of fertilizer application

B1: Broadcasting

B2: Band placement

3.4.2 chart 1 : Sub Plot treatments (four): Number of splits of recommended dose of fertilizer:

T1	Recommended dose of N and K in five splits (Basal 10% and remaining dose at 45, 75, 90 and 120 DAP)
T2	Recommended dose of N and K in six splits (Basal 10% and remaining dose at 45, 75, 90, 120 and 150 DAP)
T3	Recommended dose of N and K in seven splits (Basal 10% and remaining dose at 45, 75, 90, 120, 150 and 180 DAP)
T4	Recommended dose and schedule of nutrient applications (Half of total N and full dose of P and K at planting and rest of the N at 45 and 90 DAP)

3.5 Soil analysis:

Soil samples were collected at 0, 15, 30, 45, 75, 90, 120, 150, 180 days after planting (DAP) and at harvesting. These collected soil samples were analyzed for available N and K during different crop growth stages. For the determination of pH, EC, Soil organic carbon (SOC) and available P soil samples were analyzed at the time of sowing and at harvesting.

4. Results and Discussion

4.1 Effects of Different Treatments on Soil Macronutrient Status

4.1.1. Available Nitrogen

The data related to effect of different main and sub plot treatments on available N at different time intervals presented in Table 2 indicates an overall appraisal in available N status at harvesting under

all the treatments compared to initial. This augmentation observed in N status might be directly linked to addition of N to soil through the applied fertilizer in balanced manner as also reported by Dubey *et al.* (2012). Further, examination of data elucidated that upto 45 DAP no significant increase was noticed in the available N content of soil under both sub or main plot treatments as at the time of sowing similar amount of basal dose was applied in all the treatments except T4 (3 splits) where half of the total N dose was applied at the time of sowing. This, however did not culminated in the build-up of N in T4 during initial stage which might be due to volatilization losses owing to high temperature and absence of shade due to negligible crop cover at the time of sowing. As reported by Bouwman and Boumans (2002), potential NH₃ emissions are greatest for urea among synthetic fertilizers, for which cumulative losses may account as high as 60% of applied N (Sommer *et al.*, 2004; Rochette *et al.*, 2009). After 45 DAP available N content in soil was remarkably influenced by both main and sub plot treatments.

Among the methods of fertilizer application, significantly higher values of available N were recorded in band placement (B2) compared to broadcast (B1) at all the stages after 45 DAP upto harvest. Surface broadcasting of urea may have contributed to higher volatilization and leaching losses while emissions were reduced by placement in subsurface band placement which lead to trapping of majority of ammonical N in soil. Similar findings were elucidated by Prasertsak *et al.* (2002) and de Castro *et al.* (2016). Moreover broadcasting has an additional disadvantage of N leaching in deeper layers as reported by Chen *et al.* (2016). The amount of available N gradually increased in both main and sub plot treatments with the application of each split dose which is consistent with findings of Everaarts and Willigen (1999).

Among number of splits, T4 reported significantly higher values of available N from 75 DAP (134.51 kg ha⁻¹) upto 90 DAP (147.08 kg ha⁻¹) and thereafter it was significantly highest in T1 from 120 DAP (142.63 kg ha⁻¹) to 150 DAP (162.11 kg ha⁻¹) which corresponds to the higher amount of fertilizer N applied in these time intervals through the respective split applications under these treatments. These findings are in congruence with those of (Kamble and Kathmale, 2015). However, from 180 DAP (153.35 kg ha⁻¹) till harvest (145.93 kg ha⁻¹) decreasing trend was observed in available N in soil under T1 due to no further fertilizer application. T4 also registered a consistent fall in available N content in soil after 90 DAP (147.08 kg ha⁻¹) upto harvesting (118.31 kg ha⁻¹). In T2 from 75 DAP (125.63 kg ha⁻¹) upto 180 DAP (159.21 kg ha⁻¹) increase in available N was observed which decreased at harvest (151.78 kg ha⁻¹) its. However, in T3 available N content in soil kept on increasing significantly from 75 DAP (124.46 kg ha⁻¹) upto harvesting (157.01 kg ha⁻¹) both of which can be attributed to retention of unutilized urea applied from later splits in soil as sugarcane crop utilizes most of the applied nutrient upto 150 DAP (Dayo-Olagbended *et al.*, 2019). Interaction between different treatments (main and sub treatments) and time intervals was significant in influencing available N status in soil.

Table 2: Effect of different methods of fertilizer application and numbers of splits of N and K on available nitrogen of soil

Method of fertilizer application	Available N (kg ha ⁻¹)									
	0 DAP	15 DAP	30 DAP	45 DAP	75 DAP	90 DAP	120 DAP	150 DAP	180 DAP	Harvest
B1-Broadcasting	110.44	116.70	119.54	122.80	125.73	135.11	139.21	142.01	142.80	140.60
B2-Band Placement	110.80	118.72	121.79	124.62	131.86	141.55	145.17	148.10	148.66	145.91
SEm±	1.03	0.71	0.69	0.37	0.43	0.50	0.43	0.78	0.68	0.72
CD (P=0.05)	NS	NS	NS	NS	2.82	3.301	2.85	5.14	4.49	4.72
Number of splits of N and K										
T1-5 splits	110.45	117.58	120.30	123.11	130.66	142.63	153.10	162.11	153.35	145.93
T2 -6 splits	110.48	117.50	120.50	123.61	125.63	133.76	141.02	147.26	159.21	151.78
T3 -7 splits	110.84	118.01	121.13	124.00	124.46	129.86	135.60	139.55	146.96	157.01
T4-3 splits	110.72	117.76	120.73	124.13	134.51	147.08	139.06	131.31	123.40	118.31
SEm±	0.66	0.81	0.83	0.64	0.64	0.69	0.67	1.01	0.87	0.87
CD (P=0.05)	NS	NS	NS	NS	2.02	2.15	2.08	3.15	2.71	2.72

Fig 1: Effect of different methods of fertilizer application and numbers of splits of N and K on available nitrogen of soil

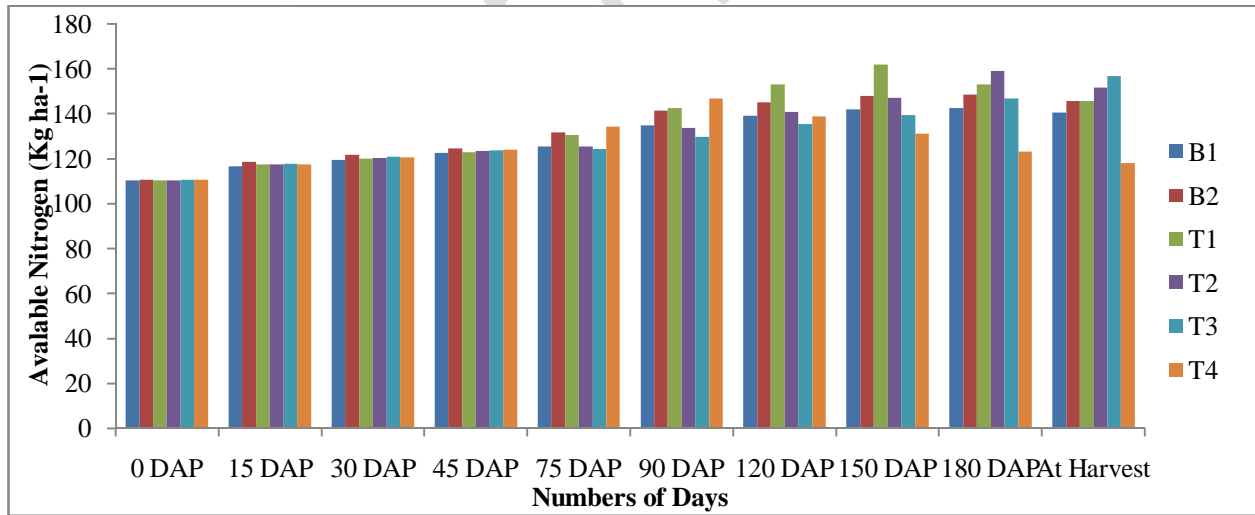
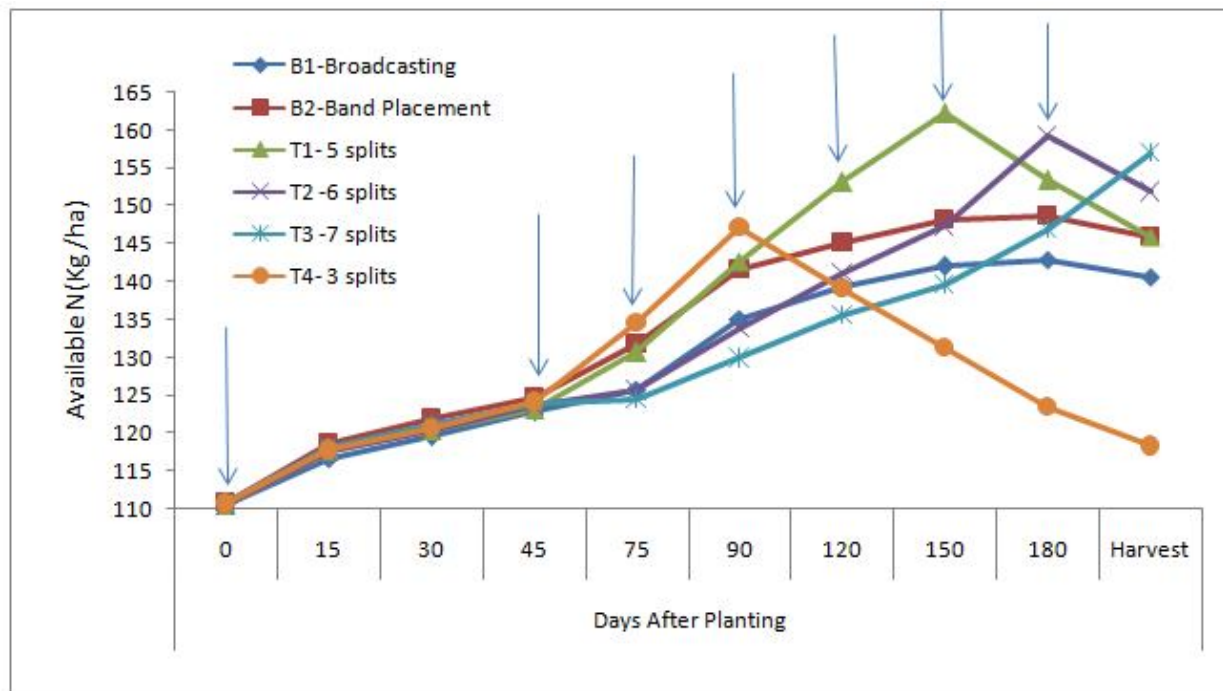


Fig 2: Effect of different methods of fertilizer application and numbers of splits of N and K on available nitrogen of soil (arrows represent timing of fertilizer application)



4.1.2 Soil Available K

The data presented in Table 3 revealed a fair appreciation in available K status at the time of harvesting compared to initial status under both main and sub plot treatments. The rise in available K might be attributed to frequent addition of K through a number of split applications of RDF throughout the crop period at different time intervals which enriched the soil in available K as argued by Pandey *et al.* (2019) and Tariq *et al.* (2011). Moreover, Singh *et al.* (2019) opined that K drawn by roots from lower layer is deposited in surface layer which finally leads to enhancement in available K status in Alfisols which might be the case here as sugarcane is a deep rooted crop capable of drawing sizeable amount of K from subsurface layer.

Among different methods of fertilizer application, significantly higher values of available K were recorded in band placement (B2) compared to broadcast (B1) at all the time intervals upto harvest. However, the difference noted was non significant at 0, 150, 180 DAP and at harvest. This might be accredited to slow downward movement of K arising from accelerated adsorption of K on soil colloidal complex as a result of wider soil fertilizer (Nand *et al.*, 2019) contact in broadcasting. Moreover K uptake might be higher in band placement leading to more exhaustion of nutrient applied in the vicinity of plant roots. Similar observations were annotated by Kraska *et al.* (2021).

At 0 DAP, available K content observed in all the sub treatments were at par with each other. Among different number of splits applied, treatment receiving fertilizer in three splits (T4) reported highest values of available K upto 75 DAP (225.30 kg ha⁻¹) as it received the whole amount of RDF to be

applied before 90 DAP which was higher than other treatments. Thereafter treatment T1 exhibited significantly higher available K values upto 150 DAP (222.06 kg ha⁻¹) while at 180 DAP and at the time of harvesting, significantly higher values of available K were observed in treatments T2 (225.10 kg ha⁻¹) and T3 (227.48 kg ha⁻¹) respectively which might be due to higher application of fertilizer K compared to other treatments during these time intervals through the scheduled splits in respective treatments. These findings are in compliance with those of and Pandey *et al.* (2019) who reported an increase in soil available K in when applied in splits. Treatment T4 reported a fall in available K content in soil 45 DAP after initial rise at 15 DAP upto harvesting while in T1 and T2 it was decreased after 150 and 180 DAP respectively upto harvesting. This drop in soil might be attributed to non application fertilizers at these intervals as per findings of Nand *et al.* (2019) . Interaction between different treatments (main and sub treatments) and time intervals was significant in influencing available K status in soil.

Table 3: Effect of different methods of fertilizer application and numbers of splits of N and K on available potassium of soil

Methods of fertilizer application	Available K ₂ O (kg ha ⁻¹)									
	0 DAP	15 DAP	30 DAP	45 DAP	75 DAP	90 DAP	120 DAP	150 DAP	180 DAP	Harvest
B1-Broadcasting	201.40	216.08	218.33	221.19	222.02	216.97	213.37	217.84	220.43	220.50
B2-Band Placement	201.25	213.69	215.82	218.69	217.11	212.59	206.71	209.81	213.37	214.6
SEm±	0.53	0.09	0.39	0.04	0.47	0.60	1.00	1.55	2.44	1.16
CD (P=0.05)	NS	0.63	2.59	0.28	3.12	3.96	6.57	NS	NS	NS
Number of splits of N and K										
T1 -5 splits	201.28	206.66	208.61	210.70	220.83	218.33	215.25	222.06	220.41	218.75
T2 -6 splits	201.50	206.01	207.31	209.40	217.78	215.28	211.16	217.88	225.10	223.76
T3 -7 splits	201.55	205.10	207.11	210.40	214.40	211.73	208.23	212.78	220.50	227.48
T4-3 splits	200.00	241.76	245.26	249.26	225.30	213.78	205.53	202.59	201.59	200.21
SEm±	1.00	0.75	0.82	0.76	0.92	0.90	0.72	0.67	1.06	0.64
CD (P=0.05)	NS	2.33	2.56	2.37	2.88	2.82	2.25	2.57	3.28	1.99

Fig 3: Effect of different methods of fertilizer application and numbers of splits of N and K on available potassium of soil

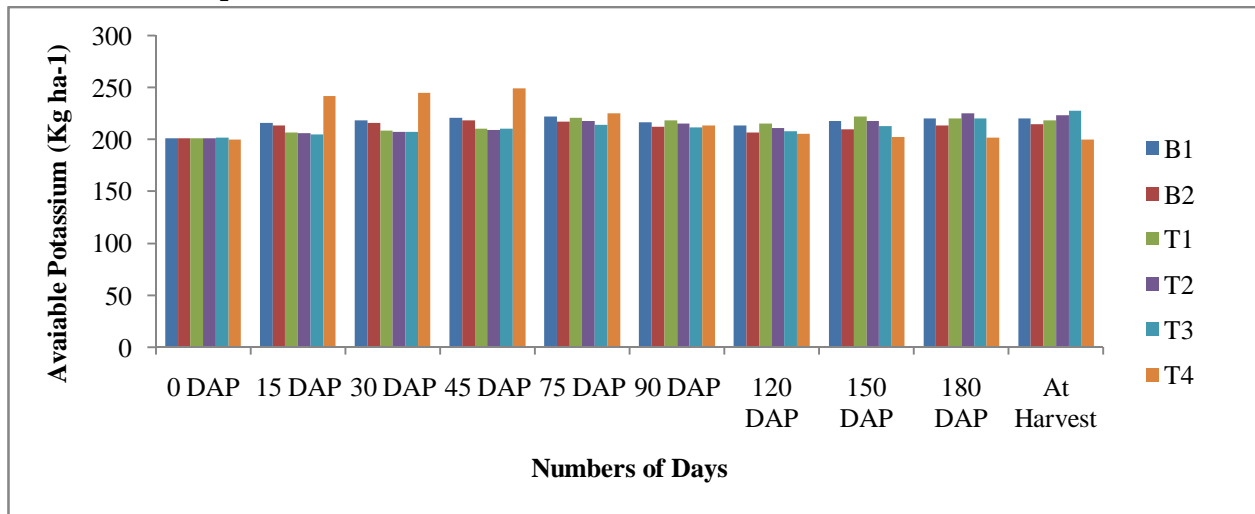
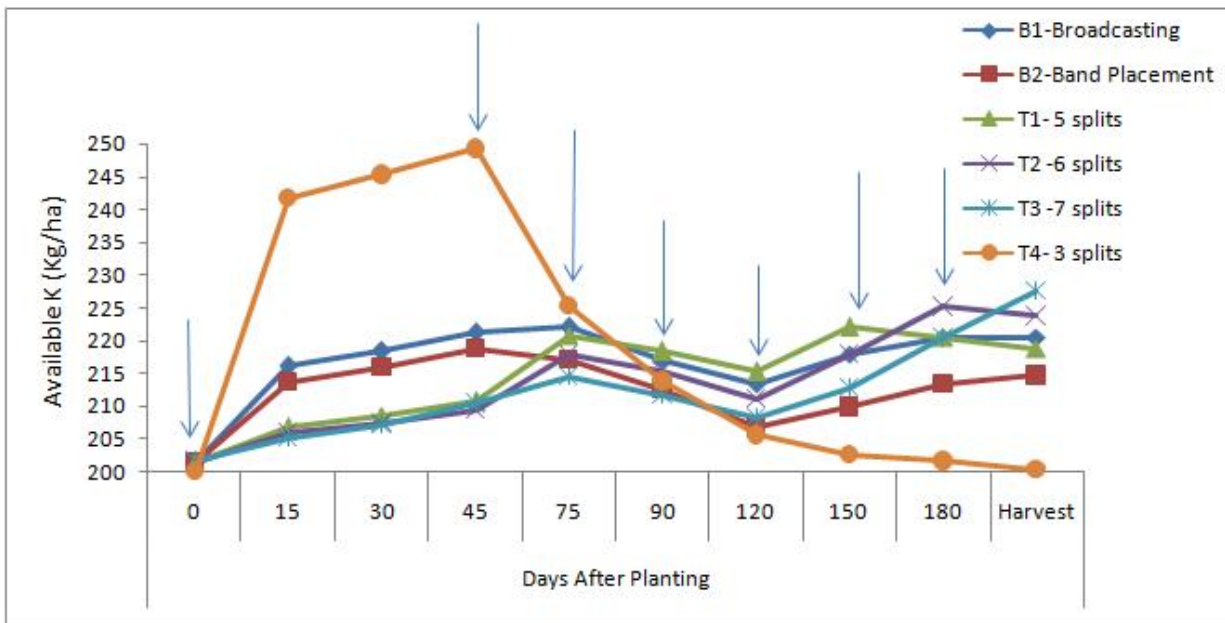


Fig 4: Effect of different methods of fertilizer application and numbers of splits of N and K on available potassium of soil (arrows represents timing of fertilizer application)



4.1.3 Available Phosphorus

It is clear from the perusal of data in Table 4 that at harvesting, different splits of N and K applied had non- significant effect on P_2O_5 content of soil. When effect of broadcasting and band placement were compared it was seen that soil P_2O_5 content recorded was significantly higher in broadcasting (B1) than band placement (B2) which might be due to fixation and retention of unutilized P as a result of higher soil to fertilizer contact (Rehman *et al.*, 2006). An increment in available P values was noticed in all the

treatments at harvesting which might be associated to application of mineral fertilizers at the time of sowing (Kraska *et al.*, 2021).

Table 4: Effect of different methods of fertilizer application and numbers of splits of N and K on available phosphorus and soil organic carbon of soil

Method of fertilizer application	P ₂ O ₅ At sowing (kg ha ⁻¹)	P ₂ O ₅ At harvest (kg ha ⁻¹)	SOC At sowing (%)	SOC At harvest (%)
B1 -Broadcasting	18.62	24.63	0.48	0.50
B2 - Band placement	19.62	21.68	0.48	0.51
SEm±	0.10	0.38	0.03	0.01
CD (P=0.05)	NS	3.057	NS	NS
Number of splits of N and K				
T1 - 5 splits	18.71	22.36	0.47	0.48
T2 - 6 splits	18.88	22.96	0.47	0.49
T3 - 7 splits	19.36	23.28	0.48	0.50
T4 - 3 splits	18.80	24.01	0.48	0.48
SEm±	0.40	0.58	0.06	0.02
CD (P=0.05)	NS	NS	NS	NS

4.2 Effects of Different Treatments on Soil Chemical Properties

4.2.1 Soil Organic Carbon

It is very much clear from the data presented in Table no. 4 that no significant changes were recorded in the organic carbon content of initial soil samples and those collected at harvest. Neither method of fertilizer application and nor the number of split applied had any significant influence on organic content of the soil. However a slight increase in numerical value was observed at harvesting with respect to organic carbon content at harvesting which might be due to suppressive effect of N fertilization on microbial mineralization of soil organic matter. Addition of ammonium molecules through urea application in splits throughout the life cycle of crop reduced oxidative enzyme activity (Mahal *et al.*, 2019) by inhibiting synthesis of ligninolytic enzymes released by ligninolytic fungi (Khalafalla and Hamed, 2015).

4.2.2 Soil pH and EC (dS m⁻¹)

Changes undergone in pH and EC of the soil during the crop growth are presented in Table 5 which shows no remarkable variations in pH and EC of the soil either under the main plot treatments (methods of fertilizer application) or sub plot treatments (application of RDF in different splits). This might be due to strong buffering capacity of clay soils of the experimental site. However a slight decrease in soil pH values was observed in all the treatments at harvesting relative

to initial values which might be release of root exudates and accumulation of other decomposition products which are acidic in nature. Moreover application of urea also had an acidic residual effect in soil causing a fall in pH values (Dayo-Olagbende *et al.*, 2019; Kraska *et al.*, 2021)..

Table 5: Effect of different methods of fertilizer application and numbers of splits of N and K on pH and EC of soil

Method of fertilizer application	Initial pH	pH At Harvest	Initial EC (dSm ⁻¹)	EC At Harvest (dSm ⁻¹)
B1-Broadcasting	8.23	8.13	0.25	0.16
B2- Band placement	8.20	8.16	0.26	0.16
SEm±	0.00	0.01	0.01	0.03
CD (P=0.05)	NS	NS	NS	NS
Number of splits of N and K				
T1- 5 splits	8.15	8.12	0.26	0.16
T2 - 6 splits	8.25	8.15	0.26	0.16
T3 - 7 splits	8.21	8.15	0.25	0.17
T4- 3 splits	8.25	8.17	0.25	0.17
SEm±	0.02	0.06	0.02	0.06
CD (P=0.05)	NS	NS	NS	NS

5. Conclusion:

Based on the observations recorded and intensive interpretation of the results it can be concluded that band application of N fertilizer is an effective strategy for enhancing the availability of N in soil while banding of K is effective in enhancing the absorption of nutrient by plant roots. However increasing the number of splits beyond five is not helpful to crop as most of the absorption of required nutrients occur during vegetative stage and thus fertilizer applied at latter stages remains unutilized and is lost through various mechanisms. Providing excessive amount of fertilizer at sowing is also not very productive as plant roots are not developed in early stages and thus applied N can be lost through volatilization and leaching. Thus it can said that increasing and decreasing the no. of splits before or after peak nutrient requirement stages of crop are not fruitful and should be adjusted accordingly. In the case of sugarcane dividing the RDF in five splits emerged out to be best treatment.

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