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Effect of crop residue incorporation and potassium releasing bacteria (KRB) on growth and available nutrient status of Maize (*Zea mays* L.)

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Abstract
A field experiment was carried out at Agricultural College Farm, Bapatla during *rabi* 2021. In order to study the impact of crop residue incorporation and potassium releasing bacteria (KRB) on the growth and available nutrient status of maize (*Zea mays* L.) The experiment was laid out in a Randomized Block Design with ten treatments replicated thrice. The treatments comprised of T1: Control, T2: KRB alone, T3: 50% RDK+KRB, T4: 75% RDK+KRB, T5: 100% RDK alone, T6: 100% RDK+ KRB, T7: 50% RDK+50% K through rice straw incorporation, T8: 75% RDK + 25% K through rice straw incorporation, T9: 50% RDK + 50% K through rice straw incorporation + decompo A & B, T10:75% RDK + 25% K through rice straw incorporation+ decompo A & B. The results revealed that application of 100% RDK along with KRB and 75% RDK + 25% K through rice straw along with decomposers showed the significant effect on plant height, drymatter production, grain and stover yield and available potassium status in soil found superior over the rest of treatments.

Keywords: Rice straw incorporation, KRB, decomposers, growth, grain yield and stover yield

Introduction
Maize (*Zea mays* L.) is the most versatile crop among cereals with respect to its adaptability, types and uses. Globally, maize is also known as "Queen of cereals" due to its higher production potential and wider flexibility under different climatic and soil conditions. Grower's interest towards maize has been increasing due to its high production potential and variety of industrial uses, growing weird weather patterns and inadequate supply of water for rice cultivation.

In India maize is cultivated in 9.86 million hectares and the production and productivity were 31.51 m t and 3195 kg ha^{-1}, respectively and productivity *of kharif* and *rabi* were 2745 kg ha^{-1} and 4908 kg ha^{-1}, respectively. In Andhra Pradesh the area of maize under cultivation is 0.3 m ha, production is 1.95 m t and productivity are 6438 kg ha^{-1} whereas kharif and rabi maize productivity were 3807 kg ha^{-1} and 8025 kg ha^{-1}, respectively (DoES-, 2020-2021) [2].

Crop residue incorporation is an environment friendly strategy which is becoming a common soil management practice for sustainability of soil fertility. About 25% of N and P, 50% of S and 75% of K taken up by cereal crops are retained in the crop residue, making them viable nutrient sources. Also, residues return carbon (C) to the soil, which improves soil structure, the ability of the soil to hold nutrients, and water holding capacity. Straw contains useful quantities of potash (K_2O) and phosphate (P_2O_5). Incorporation of crop residues can contribute to sustainability mainly through improvement of soil fertility as judged by organic carbon, available P and potassium (K) content. Straw incorporation returns valuable nutrients back into the soil, particularly P and K, leading to potential economic savings through reducing the requirement for inorganic fertilisers. Ironically about 75% of K uptake was retained in the paddy straw making it as valuable nutrient sources and considering high variability in K response of cereal crop the blanket K recommendation may lead to economic loss for farmers due to under or over application in most of the cases.

K fertilizer cost has increased considerably over the years. The sharp increase in price has raised doubts about the alternate sources of K application in cereal crops.

After nitrogen and phosphorus, potassium is considered as an essential macronutrient and it is the major constituent with in living cells with distinct role to play in plant metabolism and required in huge quantities by most of the crops. Although most soils contain huge amounts of K as a key part of the matrix, many times the soil fails to supply sufficient amount of

potassium to meet the needs of the plants and responses were observed to its application.

It is proven that microbial soil community is able to influence soil fertility through soil process *viz.*, decomposition, mineralization and storage or release of nutrients (Parmar and Sindhu, 2013) [7]. Among these microorganisms, Potassium Releasing Bacteria (KRB) has attracted the attention of agriculturalists as soil inoculums to promote the plant growth and yield.

The KRB are effective in releasing potassium from inorganic and insoluble pools of total soil K through solubilisation. Potassium is fixed with in the soil and not easily meet the crop demand. Although, most of the agricultural soils here large quantities of K, these are immobilized and mostly become unavailable. Hence, the application of potassium (K) releasing microorganisms is a promising approach for increasing K availability in soil. Keeping all these factors in mind, the present investigation was conducted to investigate the effect of crop residue incorporation and KRB on growth and available nutrient status of maize (*Zea mays* L.) at Agricultural College Farm, Bapatla, Andhra Pradesh

Material and Methods

A field experiment was carried out during *rabi* season of 2021 at Agricultural College Farm, Bapatla to study the impact of crop residue incorporation and potassium releasing bacteria (KRB) on the growth and available nutrient status of maize (*Zea mays* L.) The experiment was laid out in a Randomized Block Design with ten treatments replicated thrice. The treatments comprised of T1: Control, T2: KRB alone, T3: 50% RDK+KRB, T4: 75% RDK+KRB, T5: 100% RDK alone, T6: 100% RDK+ KRB, T7: 50% RDK+50% K through rice straw incorporation, T8: 75% RDK + 25% K through rice straw incorporation, T9: 50% RDK + 50%K through rice straw incorporation + decompo A & B, T10:75% RDK + 25% K through rice straw incorporation+ decompo A & B.

The experiment soil and paddy straw used in the study were analysed before the initiation of experiment and at harvest of the crop was collected were shade dried, gently ground with wooden hammer, sieved through 2 mm sieve and analyzed for pH in 1:2.5 soil: water suspension, organic carbon by the Walkely and Black (1934) [10] method, available N by alkaline potassium permanganate suggested by Subbiah and Asija (1956) [9], available P (Watanabe and Olsen, 1965) [11], available K by extraction of soil with neutral ammonium acetate solution at pH 7.0 (Jackson 1973) [5]. The hybrid used in the study was Pioneer 3396. The soil of the experimental site was sandy clay in texture with a pH of 7.46, electrical conductivity of 0.28 dS m^{-1}, medium in organic carbon (5.5 g kg^{-1}), available nitrogen (210 kg ha^{-1}), available phosphorus (44.6 kg P2O5 ha^{-1}) and available potassium (332kg K_2O ha^{-1}). Nutrient composition in the paddy straw used in the study contains 0.56% of N, 0.19% P and 2.25% K. Recommended dose of nitrogen, phosphorus and potassium were supplied through urea, single super phosphate (SSP) and muriate of potash (MOP), respectively. Recommended dose of nitrogen and phosphorus were applied uniformly to all the plots. Whereas potassium is applied as per the treatment. Entire quantity of phosphorus was applied as basal two days before sowing, whereas nitrogen was applied in four equal splits (¼ each at the time of sowing, knee high, between knee high-tasseling and tasseling stages). Potassium is applied in two splits (½ at the time of sowing and the remaining ½ at the time of tasseling stage). Crop residue (paddy straw) along with decomposers was incorporated one month before sowing. Biofertilizers namely Potassium Releasing Bacteria (KRB) was applied one week before sowing along with FYM.

Results and Discussion

Residue incorporation and KRB in soil is likely to bring about changes in the availability and transformation of essential plant nutrients, which ultimately affect the crop yield.

Plant Height

The data pertaining to the plant height was assessed during knee high, tasseling and harvest stages of the maize crop (Table 1) and concluded that application different levels of crop residue incorporation and potassium releasing bacteria along with different levels of potassium fertilizer showed the significant difference on plant height. Among all the treatments significantly highest plant height was recorded with the application of 100% RDK + KRB (83 cm, 231 cm and 243 cm) which was on par with 75% RDK + 25% K through rice straw incorporation along with decomposers (77 cm, 225 cm and 239 cm) at knee high stage, tasseling stage and at harvest stage respectively. Lowest plant height was recorded in the treatment control (60 cm, 182 cm and 187 cm) at all the stages of crop respectively. The increase in the growth attributes like plant height might be due to improvement might also be attributed to certain growth promoting substances secreted by the biofertilizers which in turn might have led to better root development, better transportation of water, uptake and deposition of nutrients. These results were in conformity with the finding of Parmar and Sindhu (2013) [7] and Archana *et al*., (2012) [1]. Also, the addition of crop residues and additional fertilization which might have improved the soil health and consequently higher uptake of available nutrients from the soil. Similar results were reported by Kumar *et al*. (2009)

Drymatter Accumulation

The perusal of the data on drymatter accumulation was assessed during knee high, tasseling and harvest stage of the maize crop and the data pertaining to drymatter accumulation (Table 2) indicated that, among all the treatments significantly highest dry matter accumulation was resulted in treatment with 100% RDK + KRB (932 kg ha^{-1}, 3226 kg ha^{-1} and 9095 kg ha^{-1})which was on par with 75% RDK + 25% K through rice straw incorporation along with decomposers (902 kg ha^{-1}, 3013 kg ha^{-1} and 8947 kg ha^{-1}) respectively at knee high, tasseling and harvest stage of the maize Lowest drymatter accumulation with 705 kg ha^{-1}, 1877 kg ha^{-1} and 7114 kg ha^{-1} was recorded in control. The biofertilizers has the capacity to reduce the leaching losses by fixation of nutrients and converts the unavailable form of nutrients to available form and increases the nutrient availability to plant which has positive influence on drymatter accumulation in plant. Similar results were observed by Basak and Biswas (2010).

Grain and Stover Yield

The data on the grain yield and stover yield of the maize crop was assessed (Table 3) and the results revealed that maximum grain and stover yield (3360 and 5349 kg ha^{-1}) of the maize crop was recorded in the treatment with 100% RDK + KRB and it was on par with treatment T75% RDK + 25% K through rice straw incorporation along with decomposers

(3283 and 5244 kg ha^{-1}). Whereas, minimum grain and stover yield (2404 and 3389 kg ha^{-1}) was observed in the treatment control. This might be due to significant increase in the number of kernels cob^{-1} and number of cobs plants^{-1} was recorded when the plants were implicated with biofertilizer and inorganic K source. Similar results were also recorded by Priya and Shashidhara, (2016) [8]. Integrated use of fertilizers with biofertilizers might be due to higher absorption of nutrients responsible for increased photosynthate accumulation and high biomass production and finally resulting in increase in the yield and yield components. The findings are in close agreements and well supported by Ghetiya *et al*. (2018) [4].

Available Nutrients (N, P, K)

The data on the soil available nitrogen, phosphorus and potassium status in soil was assessed during the harvest stage of the crop (Table 4) and the results revealed that application different levels of crop residue incorporation and potassium releasing bacteria along with different levels of potassium fertilizer did not show any significant effect on available N and P_2O_5 status but there was a significant effect on available K_2O status of soil.

Among all the treatments, the highest available nitrogen and phosphorus status (246 and 56.9 kg ha^{-1}) was recorded in the treatment with 100% RDK + KRB and minimum nitrogen content (216 and 52.3 kg ha^{-1}) was found in the treatment control but this effect was non-significant with regard to availability of nitrogen and phosphorus status of soil at harvest stage of the crop. This might be due to uniform application of recommended doses of nitrogen and phosphorus fertilizer in all the treatments. Further, it was observed that the incorporation of crop residues could improve the physical and chemical properties of the soil which in turn higher accumulation of N and P in the soil which improve the soil fertility. (Karami *et al*., 2012) [6]

With regard to available potassium status the highest potassium content (417kg ha^{-1}) in soil was recorded in the treatment with 100% RDK + KRB and it was found on par with the treatment 75% RDK + 25% K through rice straw incorporation long with decomposers (410kg ha^{-1}). Lowest potassium content (320 kg ha^{-1}) was found in the treatment control at harvest stage of the crop. This might be due to variety of soil microbes which can release soluble potassium from potassium-bearing minerals. These microbes release organic acid, which quickly dissolves rock and chelate silicon ions, releasing K ions into the soil (Friedrich *et al*., 2004) [3].

The increase in available K due to crop residue application might be attributed to the direct addition of potassium to the available pool of the soil besides the reduction of potassium fixation and release of potassium due to the interaction of organic matter with clay (Yadvindersingh *et al*., 2005).

Table 1: Effect of crop residue incorporation and potassium releasing bacteria on plant height (cm) of maize

Treatments	Knee high	Tasseling	Harvest
T_1: Control	60	182	187
T_2: KRB alone	62	184	189
T_3:50% RDK + KRB	64	187	193
T_4: 75% RDK + KRB	69	200	206
T_5: 100% RDK alone	71	202	208
T_6: 100% RDK + KRB	83	231	243
T_7: 50% RDK + 50% K through rice straw incorporation	66	190	198
T_8: 75% RDK + 25% K through rice straw incorporation	72	203	212
T_9: 50% RDK + 50% K through rice straw incorporation+ decompo A & B	68	193	201
T_{10}: 75% RDK + 25% K through rice straw incorporation+ decompo A & B	77	225	239
S.Em (+)	3.3	8.1	9.2
CD (p=0.05)	10	26	29
CV (%)	8.2	7.1	7.7

Table 2: Effect of crop residue incorporation and potassium releasing bacteria on dry matter production (kg ha^{-1}) of maize

Treatments	Knee high	Tasseling	Harvest
T_1: Control	705	1877	7114
T_2: KRB alone	716	2027	7238
T_3:50% RDK + KRB	724	2162	7318
T_4: 75% RDK + KRB	773	2617	7935
T_5: 100% RDK alone	803	2768	8031
T_6: 100% RDK + KRB	932	3226	9095
T_7: 50% RDK + 50% K through rice straw incorporation	752	2310	7605
T_8: 75% RDK + 25% K through rice straw incorporation	815	2807	8178
T_9: 50% RDK + 50% K through rice straw incorporation+ decompo A & B	762	2493	7745
T_{10}: 75% RDK + 25% K through rice straw incorporation+ decompo A & B	902	3013	8947
S.Em (+)	27.9	93.5	279.7
CD (P=0.05)	89.1	299	895
CV (%)	6.1	6.4	6.1

Table 3: Effect of Crop Residue incorporation and potassium releasing bacteria on kernel yield and stover yield of maize. (kg ha^{-1})

Treatments	Kernel yield	Stover yield
T_1: Control	2404	3389
T_2: KRB alone	2502	3439
T_3:50% RDK + KRB	2572	3685
T_4: 75% RDK + KRB	2708	4528
T_5: 100% RDK alone	2861	4781
T_6: 100% RDK + KRB	3360	5349
T_7: 50% RDK + 50% K through rice straw incorporation	2628	4136
T_8: 75% RDK + 25% K through rice straw incorporation	3026	4974
T_9: 50% RDK + 50% K through rice straw incorporation+ decompo A & B	2672	4334
T_{10}: 75% RDK + 25% K through rice straw incorporation+ decompo A & B	3283	5244
S.Em (+)	110	158
CD (p=0.05)	353	507
CV (%)	6.8	6.3

Table 4: Effect of Crop Residue incorporation and potassium releasing bacteria on macro nutrients (available N, P_2O_5 and K_2O) at harvest stage of maize (kg ha^{-1})

Treatments	Available N	Available P_2O_5	Available K_2O
T_1: Control	216	52.3	320
T_2: KRB alone	218	53.5	324
T_3: 50% RDK + KRB	220	54.0	329
T_4: 75% RDK + KRB	230	55.0	351
T_5: 100% RDK alone	237	55.1	357
T_6: 100% RDK + KRB	246	56.9	417
T_7: 50% RDK + 50% K through rice straw incorporation	222	54.2	341
T_8: 75% RDK + 25% K through rice straw incorporation	239	56.1	363
T_9: 50% RDK + 50% K through rice straw incorporation+ decompo A & B	227	54.7	347
T_{10}: 75% RDK + 25% K through rice straw incorporation+ decompo A & B	237	56.2	410
S.Em (+)	10.4	2.3	14.4
CD (P=0.05)	NS	NS	45.9
CV (%)	7.8	7.2	7.0

Conclusions

From this study it was concluded that 100% RDK along with KRB or 75% RDK +25% K through rice straw incorporation along with decomposers were proved to be the best and highly beneficial in improving the performance of maize and as well as on soil properties.

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