Effect of different rice establishment methods on soil nutrient status and carbon stock in paddy growing soils of Jagtial, Telangana, India

ABSTRACT

The study was conducted to know the nutrient status, yield, straw and harvest index in 4 different cropping systems *viz.,* (i) manual transplanting; (ii) dry direct seeding; (iii) drum seeding and (iv) machine transplanting 120 soil samples were analysed, 30 from each establishment method. The soil fertility status from different establishment methods was studied by analysing the samples for pH, EC, bulk density, organic carbon, available nitrogen, phosphorous, potassium, iron, zinc, total organic carbon and carbon stock. The study revealed that there is a significant difference in bulk density ranged high in machine transplanting (1.48 Mg m^{-3}) and low in dry direct seeding (1.45Mg m^{-3}). pH of soils was neutral to slightly alkaline in nature and iron content of soils ranged from 5.75 to 8.97 mg kg^{-1}.

Keywords: Paddy, survey in different rice establishment methods, soil nutrient status, yield, straw, harvest index

1. INTRODUCTION

Rice (*Oryza sativa* L.) is a staple food crop in India, India is the second largest producer of rice after China and has the largest area in the world devoted to rice farming (Thiyagarajan and Gujja., 2013). In 2021-2022 the cultivated area in India was 46.38 million hectares, produced about 130.29 million tonnes. In Telangana the cultivated area covered by paddy was 3.65 million hectares, production was 12.30 million tonnes (Agricultural statistics, 2022). In Jagtial total paddy cultivated area *in kharif* season was about 112853.6 hectares (Telangana state statistics, 2021). Rice was mostly cultivated by conventional method *i.e.,* puddling the soil, and transplanting the seedlings. But with increasing the labour shortage and water limitation there were new methods emerged. Rice can be grown using machinery for transplanting (Kamboj *et al*., 2013), under non-puddled conditions by or direct seeding (Yadav *et al*., 2009; Singh *et al.,* 2011). These methods were advantageous over manual transplanting, sometimes even with yield advantages and overall increased profits. Various management practices followed in different rice establishment methods could significantly influence some physical (Bhagat 2004) physico-chemical and chemical properties (Fageria *et al*., 2011). Puddling followed in manual, machine transplanting and drum seeding deteriorates soil structure and develops a hardpan (Sharma and De Datta1986). However, it was needed for reducing the weed emergence (Carman 1996, Mohanty *et a*l., 2004). In dry direct seeding only, tillage was followed without puddling might have differently influence soil properties. Harvesting with machines was followed by the farmers now a days may alter soil physical properties viz., bulk density, penetration resistance, aggregate mean-weight diameter, and surface roughness. Oxidation and reduction have a significant influence on chemistry of iron and other nutrients in submerged conditions. Iron (II) is an electron donor or a reducing agent when it oxidized to iron (III). In water logged conditions ferric compounds are reduced to ferrous forms, zinc concentrations have reduced in flooded conditions. Availability of iron is high and zinc is low in flooded conditions (Frageria *et al*., 2011). Zinc deficiency is a serious nutritional problem for upland crops reported by many scientists (Sarwar *et al*., 2013).

2. MATERIAL AND METHODS

2.1 Study area

The study was conducted in the Jagtial district covering all 18 mandals *viz*: Beerpur, Buggaram, Dharmapuri, Gollapalli, Ibrahimpatnam, Jagtial (R), Jagtial (U), Kathlapur, Kodimial, Korutla, Mallapur, Mallial, Medipalle, Metpally, Pegadapally, Raikal, Sarangapur and Velgatoor (Fig 1). The district was characterized by 10 different soil types with red soils being the predominant type. The major crops grown in Jagtial district include rice, maize, turmeric, pulses, groundnut and cotton. Rice crop grown majorly in 4 different methods, the research focused on those *viz.,* manual transplanting, dry direct seeding, drum seeding and machine transplanting.

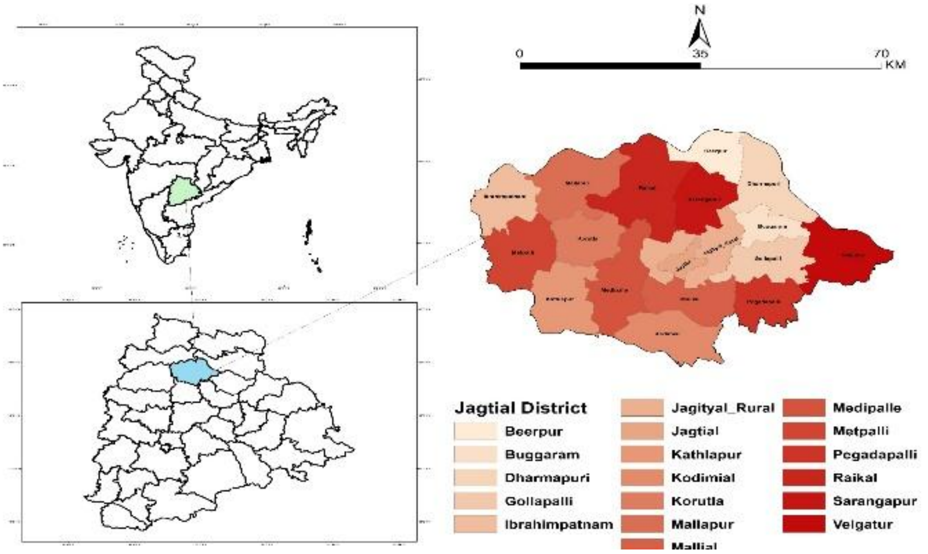

Figure 1. Location map of Jagtial district

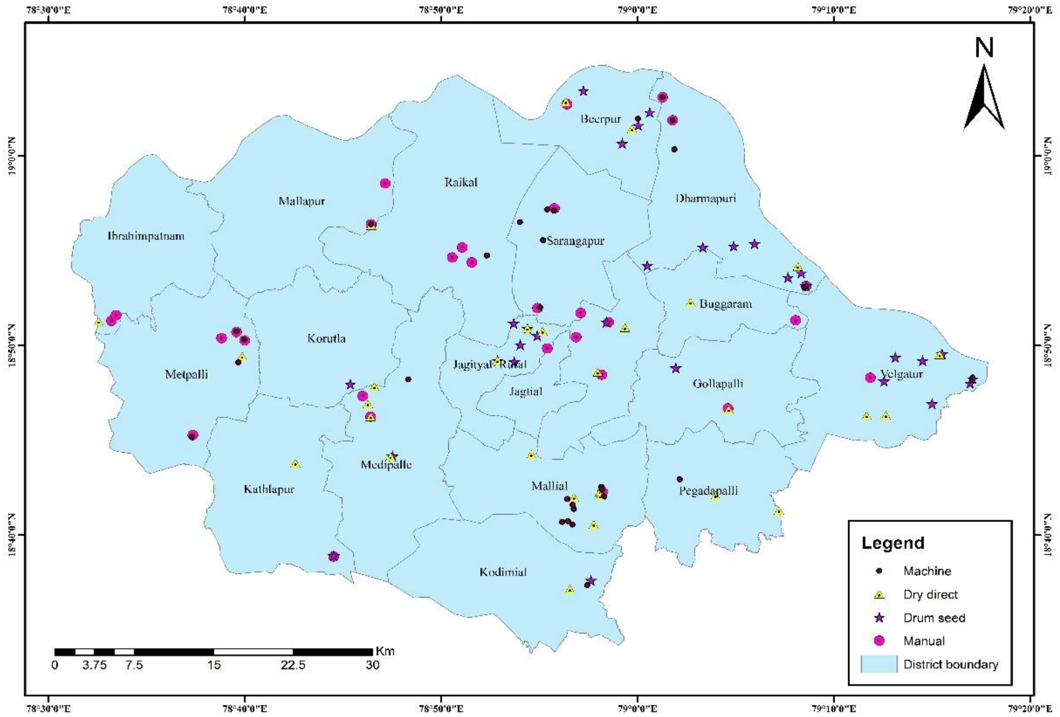

Figure 2. Location map of sample sites for different rice establishment methods in Jagtial district

2.2 Soil sampling and processing

Soil samples were collected from farmers field after harvest of *kharif,* 2022. Samples were collected at a depth of 0-15 cm. The sampling design employed a randomized zig-zag pattern, covering the entire field with 4 to 5 sites. Approximately 0.5 kg of soil sample was collected using the quartering method, where sub-samples are taken and combined to obtain a representative sample. Bulk density samples were collected using core samplers to assess the density of the soil. The collected soil samples were shade dried and ground to a finer consistency and then sieved through a 2mm sieve. The sieved soil samples were labelled with relevant details and stored for further analysis. The stored soil samples were subjected to various analyses to determine their properties and nutrient content.

2.3 Analysis of soil samples

The soil samples were further analysed for pH, EC, OC, available N, P, K, TOC, stock, Fe and Zn. pH was measured using digital pH meter and EC was determined by digital conductivity meter these methods were proposed by Jackson, 1973. Bulk density was assessed using core sampler method, given by Blake and Hartge (1986). Organic carbon was determined by wet oxidation method (Walkley and Black, 1934). Available nitrogen was assessed by using alkaline potassium permanganate method given by Subbiah and Asija (1956). Available phosphorous was determined by Olsen's method (Olsen *et al*., 1954). Available potassium was estimated by neutral normal ammonium acetate outlined by Jackson (1973). Micronutrients (Fe and Zn) were determined by Lindsay and Norvell (1978). Total soil organic carbon was estimated by the process given by Tiessen and Moir (1993) and carbon stock was calculated by the formulae C stock in soil (Mg ha^{-1}) = C content (g kg^{-1}) * Depth of soil (m)* Bulk density (Mg m^{-3}) *10, given by Anantha *et al*., 2020**.**

Statistical analysis

The data were analysed using analysis of variance (ANOVA) – one way classification. One factor ANOVA was used to determine the existence of interaction effect between rice establishment methods. The 5% probability level was regarded as statistically significant.

3. Results and discussions

3.1 Soil reaction (pH):

Soil pH is an indicator of the acidity or alkalinity of soil and has a dominant effect on plant nutrients availability (Neina, 2019). For normal growth of rice, a pH range 5.5-8.0 was suitable. pH of the selected soil sites was neutral to slightly alkaline in nature. The overall pH of soil ranged from 7.53 to 7.89 with overall mean value of 7.67. The results of collected soil samples in different rice establishment methods of Jagtial district have shown that the soil pH was neutral to slightly alkaline (Table1,3 and fig 3). Therefore, observed pH was suitable for rice cultivation in the majority area of the Jagtial district. The pH of the soils ranged from 7.27 to 7.83 (with mean of 7.68) in manual transplanting, 7.31 to 7.65 (with mean of 7.53) in dry direct seeding, 7.51 to 8.24 (with mean of 7.89) in drum seeding and 7.46 to 7.70 (with mean of 7.59) in machine transplanting. Highest pH was observed in drum seeding (7.89) followed by manual transplanting (7.68) followed by machine transplanting (7.59) and the least pH was observed in dry direct seeding (7.53). Contradictorily Lakshmi *et al*., 2019 reported that there was no significant difference in soil pH under different rice establishment methods.

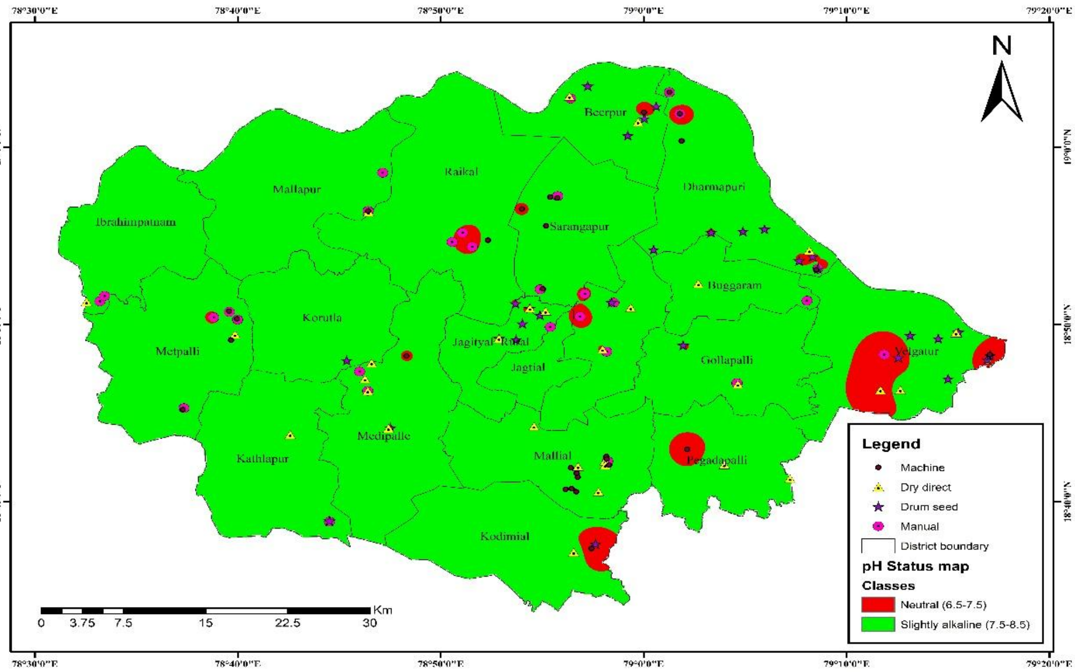

Figure 3: Soil reaction (pH) in different rice establishment methods

3.2 Electrical conductivity (dS m^{-1})

The electrical conductivity, which measures the number of soluble salts in the soil. It was influenced by cropping sequence, irrigation, land usage, and the use of fertilizers such manure and compost. High electrical conductivity represents higher degree of salinity. Excessive dissolved salts in soil solutions causes hindrance in normal nutrient uptake process either by imbalance of ions uptake, antagonistic effect between nutrients or excessive osmotic potentials of soil solution or a combination of the three effects (Rehman and Afzal, 2010). The EC of soils ranged from 0.35 to 0.56 dS m^{-1} (with mean of 0.42 dS m^{-1}) in manual transplanting, 0.26 to 0.49 dS m^{-1} (with mean of 0.35 dS m^{-1}) in dry direct seeding, 0.25 to 0.50 dS m^{-1} (with mean of

0.37 dS m^{-1}) in drum seeding and 0.31 to 0.52 dS m^{-1} (with mean of 0.37 dS m^{-1}) in machine transplanting (table 1,3 and fig 4). There was no significant variation between different establishment methods.

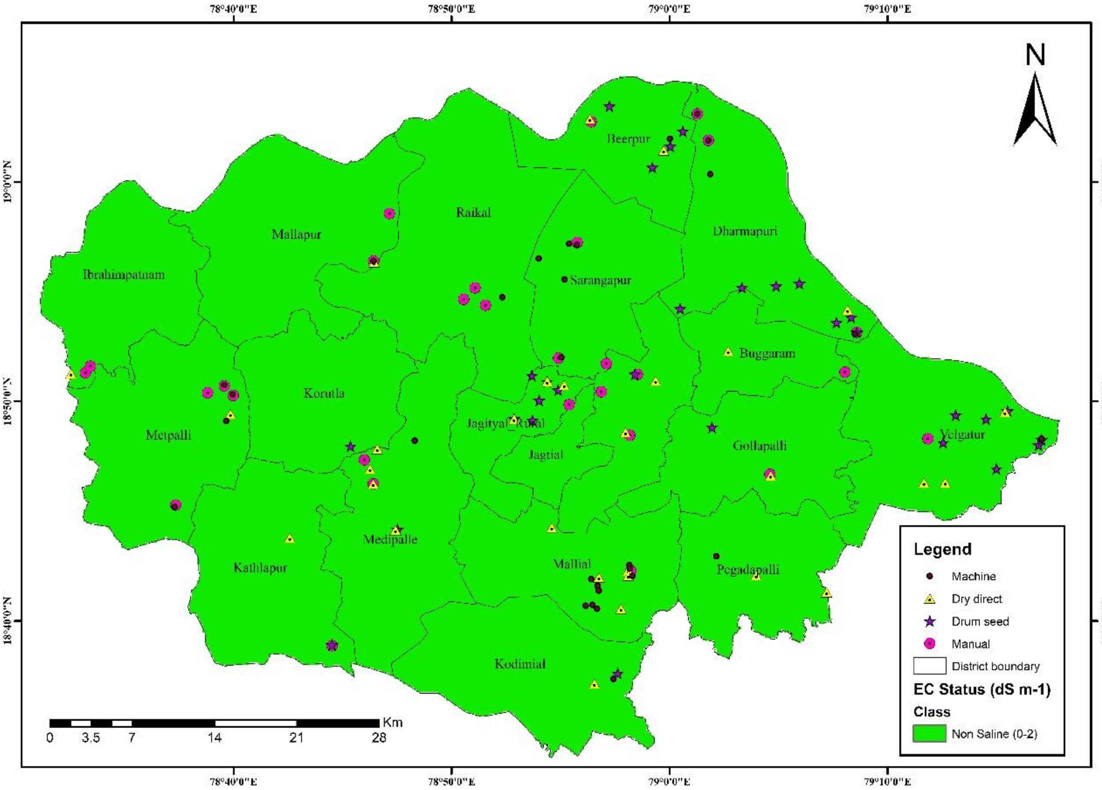

Figure 4: Electrical conductivity (dS m^{-1}) in different rice establishment methods

3.3 Organic carbon (%)

In agricultural soil, organic matter plays a crucial role. It provides plant nutrients, enhances soil structure, increases water retention and infiltration, feeds the microflora and fauna of the soil and ensures that applied fertilizer was retained and cycled (Johnston, 1986). Organic matter was a complex composition that benefits crop production, soil fertility, soil tilth and overall soil sustainability. It minimizes negative environmental impacts and thus improves soil quality (Franciosco, 2000). The OC of the soils ranged from 0.37 to 0.45 % (with mean of 0.41%) in manual transplanting, 0.38 to 0.50% (with mean of 0.43%) in dry direct seeding, 0.36 to 0.48% (with mean of 0.42%) in drum seeding and 0.34 to 0.45% (with mean of 0.39 %) in machine transplanting (table 1,3 and fig 5). There was no significant variation between different establishment methods.

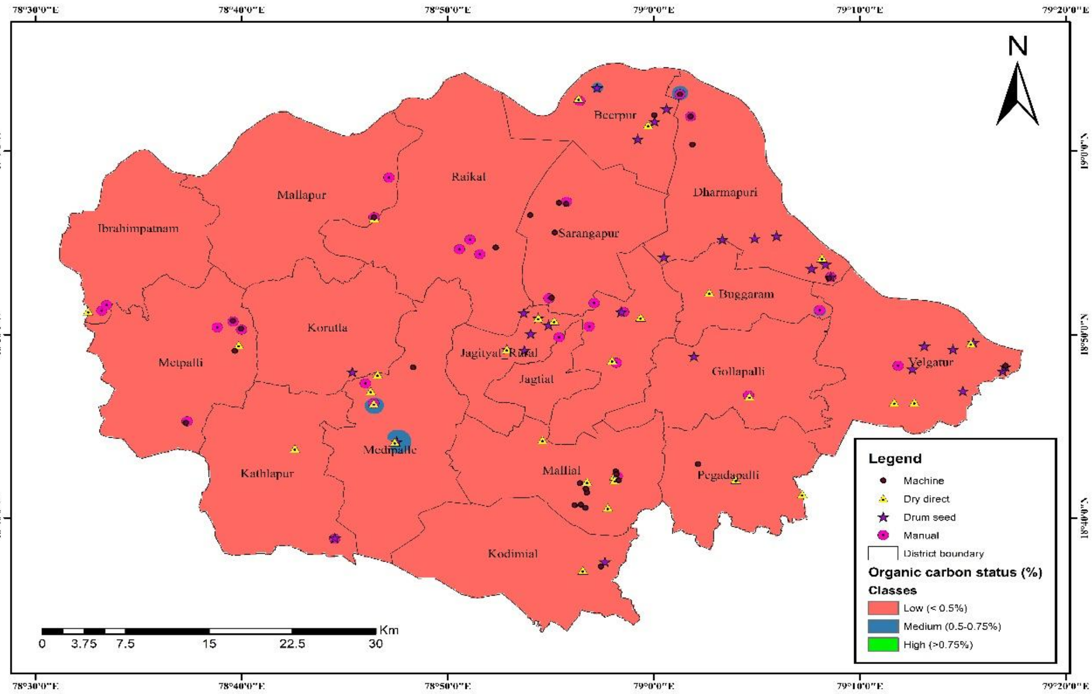

Figure 5: Soil organic carbon (%) status in different rice establishment methods

3.4 Bulk density (Mg m^{-3})

Bulk density of the soil was an indication of the compactness of the soil the compactness of the soil was due to high (or) heavy usage of machinery. The BD of the soils ranged from 1.45 to 1.49 Mg m^{-3} (with mean of 1.47 Mg m^{-3}) in manual transplanting, 1.43 to 1.48 Mg m^{-3} (with mean of 1.45 Mg m^{-3}) in dry direct seeding, 1.43 to 1.49 Mg m^{-3} (with mean of 1.46 Mg m^{-3}) in drum seeding and 1.44 to 1.51 Mg m^{-3} (with mean of 1.48 Mg m^{-3}) in machine transplanting. The bulk density (Table1 and 3) of soils in different rice establishment varied significantly which was recorded higher in machine transplanting (1.48 Mg m^{-3}) followed by manual transplanting (1.47 Mg m^{-3}), drum seeding (1.46 Mg m^{-3}) and the least in dry direct seeding (1.45 Mg m^{-3}). Usage of huge machinery for transplanting and harvesting could be the reason for greater Bd values under machine transplanting system. In all the three systems viz., machine, manual and drum seeding methods puddling was a common practice which destroys soil structure and made soil dense (Arora *et al*., 2006, Mondal *et al*., 2016), un puddled soil under dry seeding method recorded the lower values. Sharma and De-Datta (1986) reported that bulk density is high in puddled soils due to drying of soil after harvest. Contradictorily decrease in bulk density by puddling which leads to open structures has been reported by Sharma *et al*., 1988 and Bhagat *et al*., 1994.

3.5 Total Organic Carbon (%)

Total organic carbon (Table 3) of the soils ranged from 0.46 to 0.58 % (with mean of 0.53 %) in manual transplanting, 0.49 to 067 % (with mean of 0.56 %) in dry direct seeding, 0.48 to 0.62 % (with mean of 0.55 %) in drum seeding and 0.44 to 0.60 % (with mean of 0.51 %) in machine transplanting (table 1 and 3). There was no significant variation between different establishment methods.

3.6 Soil organic carbon stock (Mg ha^{-1})

Carbon stock of the soils (Table 1 and 3) was ranged from 10.4 to 12.8 Mg ha^{-1} (with mean of 11.7 Mg ha^{-1}) in manual transplanting, 10. to 14.4 Mg ha^{-1} (with mean of 12.2 Mg ha^{-1}) in dry direct seeding, 10.8 to 13.4 Mg ha^{-1} (with mean of 12.1 Mg ha^{-1}) in drum seeding and 9.8 to 13.3 Mg ha^{-1} (with mean of 11.4 Mg ha^{-1}) in machine transplanting. There was no significant difference between different rice establishment methods.

Table 1. Soil physico-chemical properties of soil under different rice establishment methods

	Manual transplanting	Dry direct seeding	Drum seeding	Machine transplantin g	CD (p=0.05)

pH	7.68	7.53	7.89	7.59	0.16
EC (dS m^{-1})	0.42	0.35	0.37	0.40	NS
OC (%)	0.41	0.43	0.42	0.39	NS
BD (Mg m^{-3})	1.47	1.45	1.46	1.48	0.02
TOC (%)	0.53	0.56	0.55	0.51	NS
Carbon stock (Mg ha^{-1})	11.7	12.2	12.1	11.4	NS

3.7 Available nitrogen (kg ha^{-1})

Nitrogen (N) is necessary for the growth of rice and was typically a nutrient that limits yields in the world's irrigated rice production (Samonte, 2006). It was pivotal in yield realization of rice. Available nitrogen of the soils ranged from 124 to 160 kg ha^{-1} (with mean of 139 kg ha^{-1}) in manual transplanting, 125 to 160 kg ha^{-1} (with mean of 141 kg ha^{-1}) in dry direct seeding, 121 to 160 kg ha^{-1} (with mean of 144 kg ha^{-1}) in drum seeding and 121 to 155 kg ha^{-1} (with mean of 138 kg ha^{-1}) in machine transplanting (table 2,3 and fig 6). There was no significant variation between different establishment methods.

3.8 Available phosphorous (kg ha^{-1})

Phosphorus is referred as the master key to agriculture because lack of available P in the soils restricts the growth of both cultivated and uncultivated plants (Foth and Ellis, 2018). Rice, like any other cereal, requires a considerable quantity of phosphorus for vigorous growth and high grain yield. Available phosphorous of soils ranged from 24.0 to 60.9 kg ha^{-1} (with mean of 41.7 kg ha^{-1}) in manual transplanting, 38.9 to 59.2 kg ha^{-1} (with mean of 50.2 kg ha^{-1}) in dry direct seeding, 26.7 to 61.3 kg ha^{-1} (with mean of 44.0 kg ha^{-1}) in drum seeding and 17.1 to 51.4 kg ha^{-1} (with mean of 36.7 kg ha^{-1}) in machine transplanting (table 2,3 and fig 7). There was no significant variation between different establishment methods

3.9 Available potassium (kg ha^{-1})

Potassium is a crucial mineral. It was essential to the majority of biochemical and physiological processes that control plant development and metabolism (Wang *et al.*, 2013). Available potassium of the soils ranged from 245 to 406 kg ha^{-1} (with mean of 343 kg ha^{-1}) in manual transplanting, 161 to 349 kg ha^{-1} (with mean of 263 kg ha^{-1}) in dry direct seeding, 198 to 363 kg ha^{-1} (with mean of 296 kg ha^{-1}) in drum seeding and 184 to 415 kg ha^{-1} (with mean of 326 kg ha^{-1}) in machine transplanting (table 2,3 and fig 8). There was no significant variation between different establishment methods.

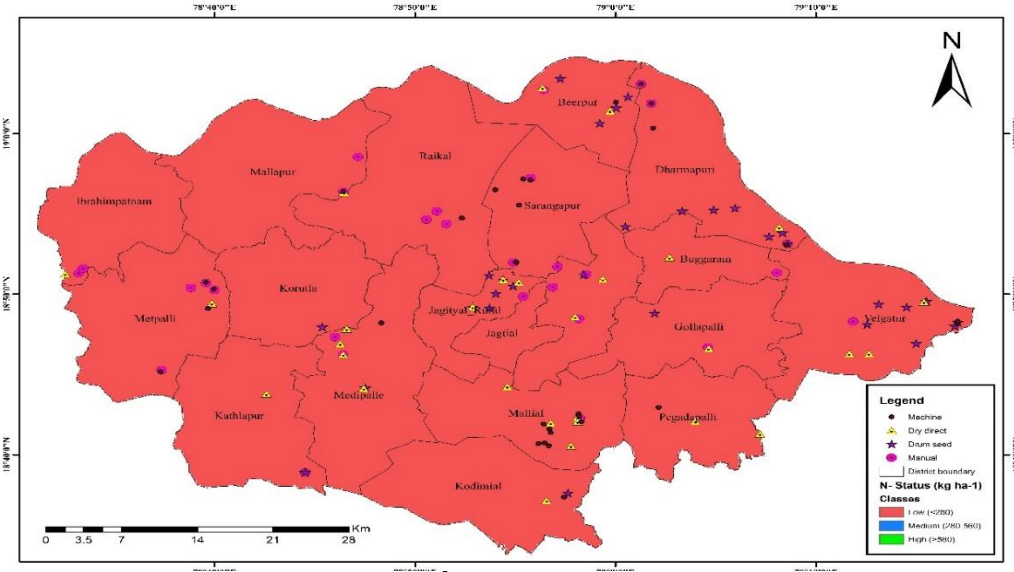

Figure 6: Soil available nitrogen (kg ha^{-1}) status in different rice establishment methods

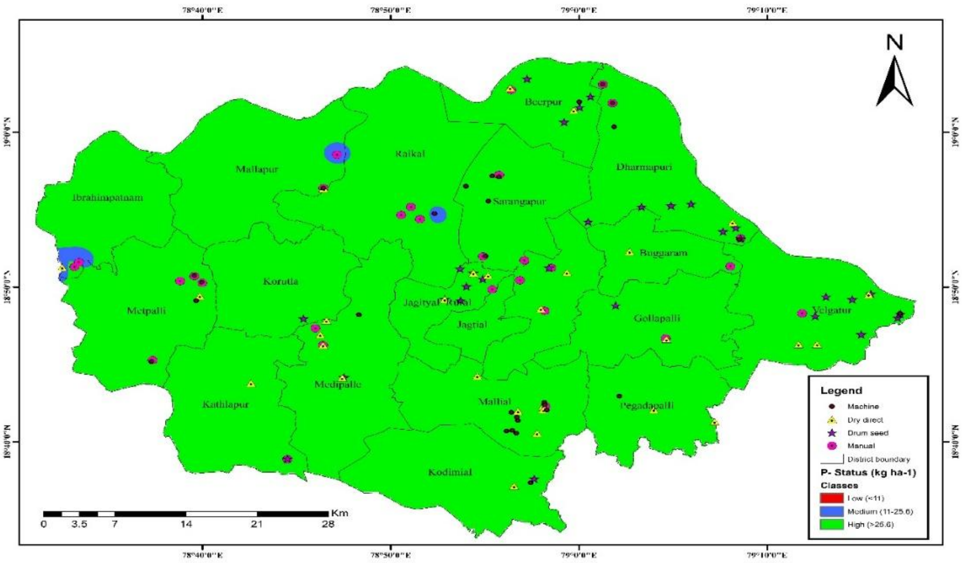

Figure 7: Soil available phosphorus (kg ha^{-1}) status in different rice establishment methods

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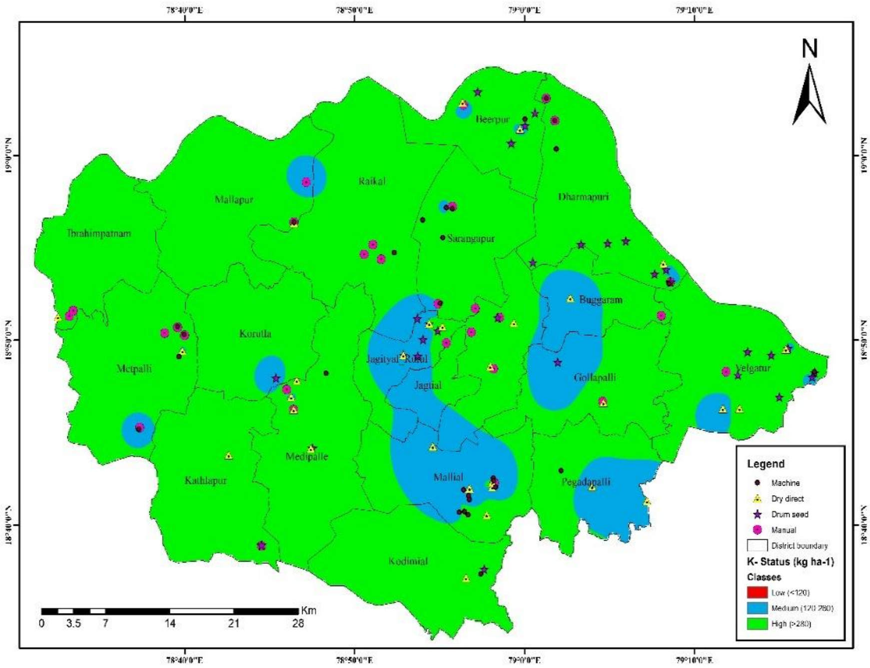

Figure 8: Soil available potassium (kg ha^{-1}) status in different rice establishment methods

3.10 Available Fe (mg kg^{-1})

Iron, has two purposes in plants one was as a structural element and the other was as a co-factor for enzyme activities (Das, 2000).The value of iron in 4 different rice establishment methods (Table 2, 3 and fig 9) ranged from 6.07 to 10.55 mg kg^{-1} (with mean of 8.08 mg kg^{-1}) in manual transplanting, 1.99 to 15.3 mg kg^{-1} (with mean of 5.75 mg kg^{-1}) in dry direct seeding, 5.42 to 10.89 mg kg^{-1} (with mean of 8.97 mg kg^{-1}) in drum seeding and 2.94 to 11.57 mg kg^{-1} (with mean of 7.54 mg kg^{-1}) in machine transplanting, the mean values varied significantly higher in drum seeding (8.97 mg kg^{-1}) and lower in dry direct seeding (5.75 mg kg^{-1}), in submerged conditions salts are leached out and the acidic cations (Al, Fe and H^{+})are predominant, the similar findings were reported by Lakshmi *et al*., 2019 the available iron recorded highest in machine transplanting and lowest in dry seed broadcasting.

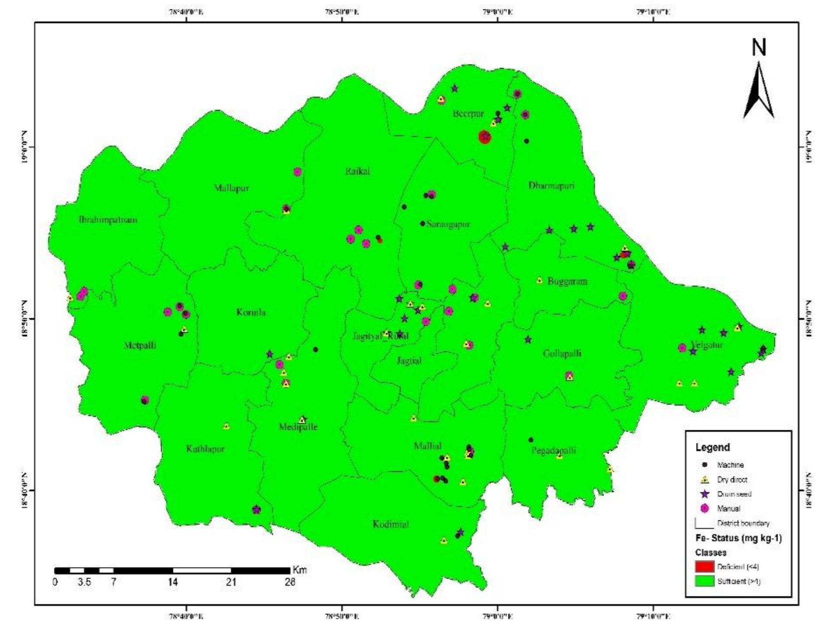

Figure 9: Soil available iron (mg kg^{-1}) status in different rice establishment methods

3.11 Available Zn (mg kg^{-1})

The proper, healthy growth and reproduction of agricultural plants depend on the eight trace elements of which zinc was one of the most important (Alloway, 2008). Available zinc of the soils ranged from 0.38 to 0.65 mg kg^{-1} (with mean of 0.54 mg kg^{-1}) in manual transplanting, 0.26 to 1.10 mg kg^{-1} (with mean of 0.51 mg kg^{-1}) in dry direct seeding, 0.38 to 1.12 mg kg^{-1} (with mean of 0.68 mg kg^{-1}) in drum seeding and 0.25 to 1.12 mg kg^{-1} (with mean of 0.58 mg kg^{-1}) in machine transplanting (table 2,3 and fig 10). There was no significant variation between different establishment methods

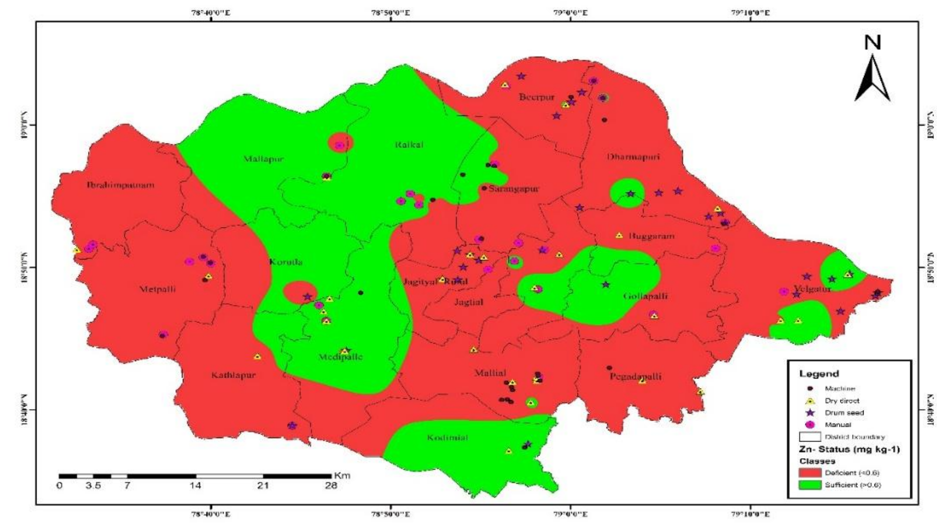

Figure 10: Soil available zinc (mg kg^{-1}) status in different rice establishment methods

3.12 Yield (kg ha^{-1})

Grain yield (kg ha^{-1}) was presented in the table 2. revealed that among the different rice establishment methods drum seeding has significantly recorded higher grain yield (6508 kg ha^{-1}) followed by machine transplanting (6108 kg ha^{-1}) which was on par with manual transplanting (6075 kg ha^{-1}) and significantly lower grain was recorded in dry direct seeding (5925 kg ha^{-1}). Similar to this Visalakshi and Sireesha (2014) and Prathiksha *et al*., 2016 reported higher yields in drum seed. This high grain yield was due to wider spacing and good penetration of light.

3.13 Straw (kg ha^{-1})

Straw yield (kg ha^{-1}) was represented in the table 2. revealed that among the different rice establishment methods drum seeding (7861 kg ha^{-1}) has significantly recorded higher straw yield which was on par with machine transplanting (7768 kg ha^{-1}) and manual transplanting

(7723 kg ha^{-1}). Significantly lower straw yield was recorded in dry direct seeding (7211 kg ha^{-1}). Prathiksha *et al*., 2016 recorded high straw yield in drum seeding.

3.14 Harvest index

Harvest index presented in the table 2. which was not significantly influenced either by different establishment methods. Similar lines were supported by Prathiksha *et al*., 2016, Lavanya and Reddy (2019).

Table 2. Soil available nutrient status, grain and straw yield of paddy under different rice establishment methods

	Manual transplanting	Dry direct seeding	Drum seeding	Machine transplanting	CD (p=0.05)
Available N (kg ha^{-1})	139	141	144	138	NS
Available P (kg ha^{-1})	41.7	50.2	44.0	36.7	NS
Available K (kg ha^{-1})	343	263	296	326	NS
Available Fe (mg kg^{-1})	8.08	5.75	8.97	7.54	2.17
Available Zn (mg kg^{-1})	0.54	0.51	0.68	0.58	NS
Yield (kg ha^{-1})	6075	5925	6508	6108	233
Straw (kg ha^{-1})	7723	7211	7861	7768	492
HI	44.2	45.3	45.4	44.1	NS

Table 3. Physico- Chemical properties and nutrient status of soil in paddy under different rice establishment methods

	Manual transplanting			Dry direct seeding			Drum Seeding			Machine transplanting		
	Min	Max	Stdv	Min	Max	Stdv	Min	Max	Stdv	Min	Max	Stdv
pH	7.27	7.83	0.18	7.31	7.65	0.10	7.51	8.24	0.23	7.46	7.70	0.08
EC (dS m^{-1})	0.35	0.56	0.07	0.26	0.49	0.07	0.25	0.50	0.08	0.31	0.52	0.06
OC (%)	0.37	0.45	0.03	0.38	0.50	0.04	0.36	0.48	0.04	0.34	0.45	0.04
BD (Mg m^{-3})	1.45	1.49	0.02	1.43	1.48	0.02	1.43	1.49	0.02	1.44	1.51	0.02
TOC (%)	0.46	0.58	0.04	0.49	0.67	0.06	0.48	0.62	0.04	0.44	0.60	0.05
Carbon Stock (Mg ha^{-1})	10.4	12.8	0.76	10.8	14.4	1.16	10.8	13.4	0.89	9.8	13.3	1.10
Available N (kg ha^{-1})	124	160	12.5	125	160	12.4	121	160	12.7	121	155	10.4
Available P (kg ha^{-1})	24.0	60.9	13.0	38.9	59.2	6.44	26.7	61.3	12.0	17.1	51.4	9.93
Available K (kg ha^{-1})	245	406	53.3	161	349	58.0	198	363	64.1	184	415	68.1
Available Fe (mg kg^{-1})	6.07	10.55	1.70	1.99	15.28	3.88	5.42	10.89	1.79	2.94	11.57	2.64
Available Zn (mg kg^{-1})	0.38	0.65	0.08	0.26	1.10	0.23	0.38	1.12	0.23	0.25	1.12	0.26

4. CONCLUSIONS

The study which is conducted in jagtial district in different establishment methods, the study revealed that soil physical chemical and physico-chemical properties have a slight significant change in the pH, bulk density and iron content the bulk density recorded highest in machine transplanting method due to high usage of machineries and lowest in dry direct seeding. the iron content is highest in flooded conditions and lowest in aerobic conditions. The nitrogen, phosphorous and potassium have no significant difference whereas grain yield and straw yield was recorded higher in drum seeding and lower in dry direct seeding.

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