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Seedling Vigour Index (SVI), weed competitiveness and root traits of aerobic rice under organic and inorganic sources nutrient management

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Abstract
A field experiment was conducted during *Kharif* 2017 and 2018 to study the effect of organic and inorganic sources of nutrients on SVI, weed competitiveness and root characteristics of aerobic rice with Integrated Nutrient Management in Aerobic rice. The experiment was laid out in split plot design with four organic sources of nutrients as main plots *viz*: M_1: Neem leaf manure @ 6 t ha^{-1}; M_2: Vermicompost @ 2 t ha^{-1}; M_3: Goat manure @ 5 t ha^{-1}; M_4: Microbial consortia [seed treatment @ 4g kg^{-1} + soil application @ 4 kg ha^{-1}] and four subplots with graded doses of fertilizers *viz*; S_1: Control; S_2: 50% RDF; $S_3$7: 5% RDF and S_4:100% RDF (120-60-40). The study revealed that inorganic nutrient level of100% RDF exhibited a significantly superior Seedling Vigor Index (15.8) and lowest (13.1) was observed with control *i.e*.,0% RDF while organic nutrient source *i.e.,* Neem leaf manure applied as a mulch, suppressed weed emergence resulted in lower weed population (3.7 no.m^{-2}) and weed dry biomass (2.9 g). Both organic nutrient sources and inorganic nutrient levels exerted a remarkable effect on root traits *viz*; root length, root biomass, root volume. Application of M_2 (vermicompost @ 2 t ha^{-1}) orM_3 (goat manure @ 5 t ha^{-1}) and fertilizer dose of 100% RDF (120-60-40) resulted in higher root length, root biomass, root volume and root-shoot ratio.

Keywords: Aerobic rice, root traits, nutrient management

Introduction
Paddy (*Oryza sativa* L.) is the principal food crop to billions of people around the World, grown over an area of 162.06 M ha globally with an annual production of 746.6 M t and productivity of 4661 kg ha^{-1} FAO, 2019-20 [1]. In Asia, rice production is a key element for economic and social stability as more than two billion people depend on rice for their dietary requirements Kadiyala, 2012 [2]. In India, it is grown in an area of 43.78 million hectares with a production and productivity of 225.51mt. 5150 kg ha^{-1}, respectively. In India, Telangana State is a key rice-producing state with 39.18 lakh hectares (Telangana State at a Glance, 2022) [3].

A huge amount of water is used for rice irrigation under the conventional water management in lowland rice consuming about 70 to 80% of the total irrigated freshwater resources in the major part of the rice-growing regions in Asia including India. Future predictions on water scarcity limiting agricultural production have estimated that by 2025, about 15-20 M ha of Asia's irrigated rice fields will suffer from water shortage in the dry season where flooded rice is the dominant cropping system. Therefore, rice could face a threat due to water shortage and hence, there is a need to develop and adopt water-saving methods in rice cultivation (Sridhar *et al.*, 2022) [4]. Aerobic rice is an alternative and contingent rice production system, wherein rice crop is cultivated under non-puddled and non-saturated soil conditions. This concept is mainly targeted for irrigated lowlands, less water available areas and uplands, which facilities for supplemental irrigation (Belder *et al.*, 2005) [5], save water input and increase water productivity by reducing water use during land preparation and limiting seepage, percolation and evaporation (Peng *et al*., 2006) [6].

Rapid uniform germination and accumulation of biomass during the initial phase of seedling establishment is an essential phenotypic trait considered as early seedling vigor for direct seeded situations in rice irrespective of environment. Enhanced role of carbohydrate, amylase, growth hormones, antioxidant enzymes and ascorbic acid brings changes in the vigour and phenotype of seedlings (Mahender, 2019) [7]. Sreedevi *et al* (2019) [8], reported higher weed competitiveness with an application of neem leaf mulch @ 6 t ha^{-1} to aerobic rice. The literature on the effect of various nutrient sources on the weed dynamics in aerobic rice was meager as most of the related research was concentrated on their effect on crop performance and quality. One of the inputs given was by Walia *et al*. (2009) [9] from Ludhiana, Punjab who noted that organic manures were more effective in suppressing weed population and weed dry matter with 100% RDF compared to other treatments in dry direct seeded rice.

Roots of plant play a fundamental role in the absorption of nutrients, water and stress tolerance affecting agricultural production. Fertilization can make important changes in root traits. The response of root growth and development to its environment is an important aspect for understanding aerobic adaptation (Bengough *et al*, 2011) [10]. In case of a higher value of root length, there is a large probability of exploring in to deeper layers and absorb more nutrients from the soil and this will help in increasing above-ground biomass and increases resistance to different stresses (drought conditions, low level of nutrients in the soil). In aerobic system, the dominant form of nitrogen is nitrate and relatively little ammonia volatilization is expected after fertilizer nitrogen application. The alternate moist and dry soil conditions may stimulate nitrification-denitrification processes in dry sown rice, resulting in loss of nitrogen through N_2 and N_2O. The differences in soil N dynamics and pathways of nitrogen losses in dry-sown rice systems may result in different fertilizer nitrogen recoveries. With even high nitrogen applications in aerobic rice, grain filling may be limited by a low contribution of post-anthesis assimilates (Zhang *et al.*, 2009) [11]. In addition, in the absence of transplanting, the roots of aerobic rice are located in the shallow surface soil, which results in a relatively low uptake of nitrogen (Zhang and Wang, 2002) [12]. Proper nutrient management not only ensures the adequate supply of fertilizers but also minimizes losses and maximize the nutrient use efficiency, under such circumstance's importance of organic manures and PGPR (plant growth promoting Rhizobacteria) is gaining prominence. Integrated nutrient management improves soil fertility besides sustaining the desired levels of crop production and productivity through the optimization of benefits from all possible sources of plant nutrients (Kundu and Pillai, 1992) [13]. It entails the conjunctive use of compost, FYM, vermicompost, crop residues, green manures, crop rotation, biofertilizers and inorganic fertilizers in a compatible manner to achieve sustainable yields. It not only reduces the dependence on chemical fertilizers but also improves the bio-physico-chemical properties *i.e.* encourage the growth and activity of mycorrhizae and other beneficial organisms in the soil, increases fertilizer use efficiency, alleviates the deficiency of secondary and micronutrients, sustains higher productivity and improved soil health (Singh *et al;* 2020) [14]. Therefore, a suitable combination of chemical fertilizers, organic manures and microbial cultures need to be developed that would result in producing rice plants with better root traits in aerobic condition. Keeping this in view, an attempt was made to evaluate the performance of aerobic rice under organic nutrient sources and graded fertilizer doses.

Materials and Methods

The present field experiment was conducted during *kharif* consecutive years, 2017 and 2018 at Research Farm, ICAR-Indian Institute of Rice Research, Rajendranagar, Hyderabad. The farm is geographically situated at an altitude of 542.6 m above mean sea level (MASL) at 17° 19' N latitude and 78 o 23' E longitude. The region is categorized under the Southern Telangana Agro-climatic zone under the semi-arid tropic region (SAT). The soils were sandy clay loam in texture with with pH of 8.14, Electrical conductivity (EC) 0.0.33 d S/m, low in organic C (0.41%), available N (208kg/ha), and high in available P (28 kg/ha) and available K (382kg/ha). Experiment was laid out in split plot design comprising of four main treatments as organic sources of nutrients *viz;*M_1: Neem leaf manure @ 6 t ha^{-1}, M_2: Vermicompost @ 2 t ha^{-1}, M3:Goat manure @ 5 t ha^{-1} and M_4: Microbial consortia (seed treatment @ 4g kg^{-1} + soil application @4 kg ha^{-1})and four sub treatments as fertility levelsS_1: Control, S_2: 50% RDF,S_3: 75% RDF and S_4: 100% RDF, replicated thrice.

The field was dry-plowed and harrowed but not puddled during land preparation. A seed rate of 30 kg ha^{-1}, treated with carbendazim 1 g kg^{-1} and the seed in the Microbial consortia treatments were treated with microbial consortia @ 4 g kg^{-1}, and the dry seed was sown at an inter-row spacing of 20 cm and intra-row spacing of 10 cm.

Observations on weeds

Weed density: Weeds were sampled in each plot before herbicide application and 10 days after herbicide application by using a quadrate of size 50 cm x 50 cm (0.25 m^2) area from two randomly fixed places in each plot and the weeds falling inside the frames of the quadrate were counted. The weed densities of each group of weeds were expressed as number per meter square in aerobic during 2017and 2018. The data was statistically analyzed after subjecting these values to square root transformation by using the following formula:

$$X = \sqrt{x+0.5}$$

Where, X = Transformed value
x = Original value

Dry matter accumulation by weeds (g m^{-2})

All the weed species (grasses, broad leaf weeds and sedges) before herbicide application and 10 days after herbicide application by using a quadrate of size 50 cm x 50 cm (0.25 m^2) area at two places in each plot were cut close to the ground surface and air dried first for 4-5 days and then in the hot air oven at 60±1 °C temperature till constant weight was obtained and expressed as g m^{-2}. The total dry matter of weeds was worked out by adding the weight of all the weed species.

Nitrogen, phosphorus and Potassium fertilizer requirement of each of the individual treatment was determined and applied in the form of urea, single super phosphate and muriate of potash, respectively. Nitrogen dosage was applied in three equal splits i.e., ⅓rd as basal ⅓rd at active tillering and remaining ⅓rd at panicle initiation stages. The entire dose of P_2O_5 was applied as basal and K_2O was applied in two equal splits ½ as basal ½ at the panicle initiation stage. Iron deficiency was observed in aerobic rice at 20-30 DAS, Ferrous sulphate @ 5 g L^{-1} was sprayed with a knapsack sprayer twice at weekly intervals.

Biometrical observations on root traits

Biometrical observations on root traits *viz*; root length, root dry weight, root volume, and root-shoot ratio were determined at 15 days intervals up to panicle initiation. The roots of five plants marked for destructive sampling were carefully removed with a shovel, thoroughly washed and separated from the shoot portion with the knife. Root length was measured using the scale from collar to tip of the longest root and expressed in cm. To measure root volume root image analysis was accomplished by the destructive method. The fresh root samples were properly washed with water and cleaned from any dirt/ decay materials. Before analysis, the roots were digitized with an Epson Perfection V 700 Photo scanner. The analysis of scanned root was carried out by RHIZO-2012 software and the volume of 5 roots was measured. The mean root volume is expressed as cc hill^{-1} and for estimating root dry weight roots were dried in an oven at 70 °C until a constant weight was obtained and was expressed as g hill^{-1}.

Table.1: Seedling vigor index (SVI) of aerobic rice as influenced by organic nutrient sources and inorganic nutrient levels

Treatment	7 DAS			14 DAS		
	2017	2018	Pooled Mean	2017	2018	Pooled Mean
Organic nutrient sources (M)						
M_1: Neem leaf manure 6 t ha^{-1}	10.1	11.1	10.6	14.1	15.2	14.6
M_2: Vermicompost 2 t ha^{-1}	10.6	13.4	12.0	14.7	15.8	15.3
M_3: Goat manure 5 t ha^{-1}	9.79	12.0	10.9	13.5	14.1	13.8
M_4: Microbial consortia 4 g kg seed^{-1} & 4 kg ha^{-1} soil application	10.9	11.8	11.4	15.4	16.3	15.9
SEm±	0.18	0.21	0.18	0.26	0.25	0.24
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Inorganic nutrient levels(S)						
S_1: 0% RDF	7.72	9.6	8.71	12.8	13.2	13.1
S_2: 50% RDF	10.2	11.6	10.9	14.6	15.3	15.2
S_3: 75% RDF	11.3	13.1	12.2	15.1	16.1	15.5
S_4: 100% RDF	12.3	14.1	13.2	15.2	16.6	15.8
SEm±	0.34	0.26	0.57	0.45	0.31	0.36
CD *(P=0.05)*	NS	NS	NS	1.32	0.91	1.05
Interaction	NS	NS	NS	NS	NS	NS

Table 2: Weed density (no. m^{-2}) and weed dry matter (g) of aerobic rice as influenced by organic nutrient sources and inorganic nutrient levels before herbicide spraying.

Treatment	Weed density (no. m^{-2})			Weed dry matter (g)		
	2017	2018	Pooled Mean	2017	2018	Pooled Mean
Organic nutrient sources (M)						
M_1: Neem leaf manure 6 t ha^{-1}	3.9 (12.4)	3.6 (15.4)	3.7 (13.9)	2.7 (7.8)	2.9 (9.3)	2.9 (7.6)
M_2: Vermicompost 2 t ha^{-1}	4.3 (16.6)	3.9 (20.1)	4.1 (16.7)	2.9 (10.2)	3.2 (10.6)	3.0 (10.6)
M_3: Goat manure 5 t ha^{-1}	5.2 (23.4)	4.9 (26.7)	5.0 (25.1)	3.5(14.1)	3.9 (17.6)	3.7 (13.4)
M_4: Microbial consortia 4g kg seed^{-1} & 4kg ha^{-1} soil application	4.2 (15.3)	3.9 (18.1)	4.1 (16.7)	3.1 (11.1)	3.4 (11.4)	3.1 (10.2)
SEm±	0.24	0.24	0.24	0.17	0.20	0.18
CD (*P=0.05*)	0.83	0.83	0.82	0.60	0.68	0.64
Inorganic nutrient levels (S)						
S_1: 0% RDF	4.2 (16.1)	3.9 (18.2)	4.0 (17.1)	3.0 (9.8)	3.2 (11.5)	3.1 (11.5)
S_2: 50%RDF	4.3 (15.6)	3.9 (19.6)	4.1 (17.3)	3.1 (10.9)	3.4 (12.8)	3.2 (11.6)
S_3: 75%RDF	4.5 (17.6)	4.1 (21.4)	4.3 (19.5)	3.3 (9.1)	3.4 (13.4)	3.3 (12.4)
S_4: 100%RDF	4.7 (18.4)	4.3 (22.2)	4.5 (20.3)	3.4 (13.2)	3.1 (14.2)	3.3 (12.5)
SEm±	0.28	0.26	0.27	0.20	1.65	0.92
CD (*P=0.05*)	NS	NS	NS	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS

Note: The data was subjected to sq. root transformations, original values are presented in parentheses

Table 3: Root length (cm) of aerobic rice as influenced by organic nutrient sources and graded fertilizer doses during *Kharif,* 2017 & 18.

Treatment	15 DAS			30 DAS			45 DAS			60 DAS			75 DAS		
	2017	2018	Pooled Mean	2017	2018	Pooled Mean	2017	2018	Pooled Mean	2017	2018	Pooled Mean	2017	2018	Pooled Mean
Organic nutrient sources (M)															
M_1: Neem leaf manure 6 t ha^{-1}	6.78	9.01	7.90	8.84	11.38	10.11	12.05	12.40	12.21	14.70	15.50	15.10	17.29	18.88	18.09
M_2: Vermicompost 2t ha^{-1}	7.90	9.61	8.76	11.29	13.73	12.51	15.05	17.61	16.34	19.26	22.01	20.64	22.66	26.20	24.43
M_3: Goat manure 5 t ha^{-1}	6.33	8.45	7.39	9.04	10.67	9.85	14.11	16.60	15.33	17.20	20.83	19.02	20.24	25.05	22.65
M_4: Microbial consortia ST 4g /kg & SA 4kg ha^{-1}	7.41	9.11	8.26	10.58	13.13	11.85	13.89	16.67	15.28	16.22	18.24	17.23	16.29	21.84	19.07
Sem±	0.34	0.23	0.21	0.47	0.21	0.32	0.63	0.27	0.42	0.81	0.34	0.53	0.94	0.41	0.63
CD (P=0.05)	NS	NS	NS	1.62	0.74	1.10	2.17	0.94	1.45	2.79	1.18	1.84	3.26	1.41	2.16
Inorganic nutrient levels (S)															
S_1: 0% RDF	4.30	5.37	4.84	6.04	6.90	6.47	8.06	8.82	8.44	10.70	11.03	10.86	12.53	13.09	12.81
S_2: 50%RDF	6.29	8.09	7.19	8.81	10.17	9.49	11.77	13.01	12.39	14.29	16.26	15.27	16.72	20.23	18.47
S_3: 75%RDF	8.39	10.51	9.45	11.73	14.28	13.01	15.67	18.26	16.97	19.03	22.83	20.93	22.26	27.22	24.74
S_4: 100%RDF	9.44	12.21	10.82	13.18	16.57	14.87	17.60	21.18	19.39	21.37	26.48	23.92	24.98	31.44	28.21
Sem±	0.28	0.31	0.18	0.40	0.29	0.40	0.54	0.37	0.27	0.67	0.46	0.33	0.78	0.55	0.39

CD (P=0.05)	0.83	0.92	0.53	1.17	0.84	0.40	1.56	1.07	0.78	1.95	1.34	0.97	2.28	1.60	1.15
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: ST: Seed Treatment, SA: Soil Application & RDF: Recommended dose of fertilizer:120:60:40 NPK

Table 4: Root biomass (g hill^{-1}) of aerobic rice as influenced by organic nutrient sources and graded fertilizer doses during *kharif*

Treatment	15 DAS			30 DAS			45 DAS			60 DAS			75 DAS		
	2017	2018	Pooled Mean	2017	2018	Pooled Mean	2017	2018	Pooled Mean	2017	2018	Pooled Mean	2017	2018	Pooled Mean
Organic nutrient sources (M)															
M1: Neem leaf manure 6 t ha^{-1}	1.76	2.57	2.17	3.42	3.76	3.59	4.92	5.40	5.16	6.67	8.26	7.46	8.46	10.44	9.45
M2: Vermicompost 2t ha^{-1}	2.16	3.16	2.66	4.26	4.73	4.50	6.93	7.16	7.04	8.88	10.45	9.66	10.64	12.49	11.57
M3: Goat manure 5 t ha^{-1}	1.47	2.16	1.82	2.95	3.24	3.10	6.64	6.82	6.73	8.43	9.94	9.18	10.16	11.88	11.02
M4: Microbial consortia ST 4g /kg & SA 4kg ha^{-1}	1.97	2.87	2.42	3.92	4.34	4.13	5.24	5.78	5.51	7.10	8.82	7.96	9.00	10.49	9.74
Sem±	0.10	0.07	0.09	0.13	0.16	0.14	0.11	0.21	0.10	0.14	0.30	0.14	0.17	0.34	0.17
CD (P=0.05)	NS	NS	NS	0.45	0.55	0.50	0.38	0.72	0.35	0.49	1.03	0.49	0.59	1.19	0.58
Inorganic nutrient levels (S)															
S1: 0% RDF	1.45	2.18	1.82	2.25	3.06	2.65	3.24	3.72	3.48	4.48	5.91	5.20	5.81	7.51	6.66
S2: 50%RDF	1.60	2.43	2.02	3.45	3.48	3.46	5.08	5.65	5.36	6.81	8.71	7.76	8.59	10.76	9.68
S3: 75%RDF	1.89	2.76	2.33	3.98	4.18	4.08	6.88	7.23	7.06	8.97	10.53	9.75	11.00	12.68	11.84
S4: 100%RDF	2.42	3.38	2.90	4.87	5.36	5.12	8.52	8.56	8.54	10.81	12.31	11.56	12.85	14.36	13.60
Sem±	0.15	0.10	0.13	0.20	0.22	0.20	0.15	0.19	0.14	0.19	0.28	0.20	0.24	0.34	0.25
CD (P=0.05)	0.43	0.30	0.37	0.59	0.65	0.43	0.42	0.56	0.42	0.56	0.83	0.59	0.70	0.99	0.73
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 5: Root volume (cc hill^{-1}) of aerobic rice as influenced by organic nutrient sources and graded fertilizer doses during *kharif*

Treatment	15 DAS			30 DAS			45 DAS			60 DAS			75 DAS		
	2017	2018	Pooled Mean	2017	2018	Pooled Mean	2017	2018	Pooled Mean	2017	2018	Pooled Mean	2017	2018	Pooled Mean
Organic nutrient sources (M)															
M1: Neem leaf manure 6 t ha^{-1}	6.79	7.17	6.98	10.04	11.08	10.78	12.52	14.72	13.12	15.82	17.69	16.75	19.38	22.57	20.98
M2: Vermicompost 2t ha^{-1}	7.62	8.43	8.03	11.64	12.78	12.21	15.92	17.31	16.62	20.78	21.99	21.39	23.96	27.03	25.49
M3: Goat manure 5 t ha^{-1}	5.29	7.11	6.20	9.47	11.01	10.24	14.90	15.88	14.89	19.21	20.90	20.06	23.53	25.41	24.47
M4: Microbial consortia ST 4g /kg & SA 4kg ha^{-1}	7.50	7.42	7.46	11.14	11.52	11.61	14.03	15.07	14.55	17.87	18.30	18.09	21.07	24.41	22.74
Sem±	0.47	0.26	0.34	0.17	0.25	0.24	0.23	0.66	0.25	0.59	0.42	0.47	0.73	0.51	0.57
CD (P=0.05)	NS	NS	NS	0.58	0.57	0.56	0.81	1.29	0.88	2.05	1.46	1.62	2.52	1.76	1.96
Inorganic nutrient levels (S)															
S1: 0% RDF	4.73	5.25	4.99	7.49	8.31	7.90	10.00	10.96	10.48	12.23	13.06	12.65	17.44	16.91	17.18
S2: 50%RDF	5.77	6.11	5.94	10.11	10.63	10.37	14.03	14.97	14.50	17.92	17.87	17.89	21.19	23.85	22.52
S3: 75%RDF	7.62	8.00	7.81	11.32	12.55	11.94	15.72	16.82	16.27	20.33	21.78	21.06	23.49	27.31	25.40
S4: 100%RDF	9.09	10.78	9.93	13.37	15.65	14.51	17.61	20.24	18.93	23.21	26.17	24.69	25.82	31.34	28.58
Sem±	0.46	0.42	0.39	0.33	0.42	0.29	0.44	0.50	0.40	0.53	0.51	0.47	0.56	0.66	0.50
CD (P=0.05)	1.35	1.22	1.13	0.95	1.22	0.86	1.28	1.47	1.16	1.55	1.50	1.36	1.64	1.94	1.47
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 6: Root-shoot ratio of aerobic rice as influenced by organicnutrient sources and graded fertilizer doses during *kharif*, 2017 & 2018.

Treatment	15 DAS			30 DAS			45 DAS			60 DAS			75 DAS		
	2017	2018	Pooled Mean	2017	2018	Pooled Mean	2017	2018	Pooled Mean	2017	2018	Pooled Mean	2017	2018	Pooled Mean
Organic nutrient sources (M)															
M1: Neem leaf manure 6 t ha^{-1}	0.47	0.60	0.54	0.42	0.45	0.43	0.32	0.36	0.34	0.29	0.32	0.30	0.26	0.29	0.27
M2: Vermicompost 2t ha^{-1}	0.48	0.64	0.56	0.43	0.47	0.45	0.37	0.40	0.38	0.33	0.36	0.34	0.32	0.34	0.33
M3: Goat manure 5 t ha^{-1}	0.46	0.59	0.53	0.41	0.44	0.42	0.34	0.38	0.36	0.32	0.34	0.33	0.29	0.32	0.31
M4: Microbial consortia ST 4g /kg & SA 4kg ha^{-1}	0.48	0.64	0.56	0.42	0.48	0.45	0.35	0.38	0.37	0.30	0.34	0.32	0.27	0.31	0.29
Mean	0.48	0.62	0.55	0.42	0.46	0.44	0.35	0.38	0.36	0.31	0.34	0.32	0.29	0.31	0.30
Sem±	0.013	0.012	0.011	0.011	0.009	0.009	0.008	0.007	0.006	0.007	0.006	0.006	0.009	0.006	0.007
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Inorganic nutrient levels (S)															
S1: 0% RDF	0.38	0.41	0.39	0.37	0.37	0.37	0.28	0.28	0.28	0.23	0.24	0.24	0.21	0.22	0.22
S2: 50%RDF	0.45	0.54	0.49	0.40	0.44	0.42	0.32	0.35	0.34	0.29	0.31	0.30	0.26	0.28	0.27
S3: 75%RDF	0.51	0.62	0.58	0.44	0.48	0.46	0.37	0.41	0.39	0.33	0.37	0.35	0.31	0.35	0.33
S4: 100%RDF	0.57	0.65	0.73	0.47	0.55	0.51	0.41	0.48	0.45	0.38	0.44	0.41	0.36	0.41	0.39
Mean	0.48	0.62	0.55	0.42	0.46	0.44	0.35	0.38	0.36	0.31	0.34	0.32	0.29	0.31	0.30
Sem±	0.014	0.043	0.008	0.012	0.039	0.006	0.012	0.030	0.005	0.008	0.026	0.004	0.012	0.024	0.006
CD (P=0.05)	NS	NS	NS	0.035	0.113	0.018	0.008	0.088	0.014	0.022	0.075	0.012	0.034	0.069	0.017
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: ST: Seed Treatment, SA: Soil Application & RDF: Recommended dose of fertilizer: 120:60:40 NPK

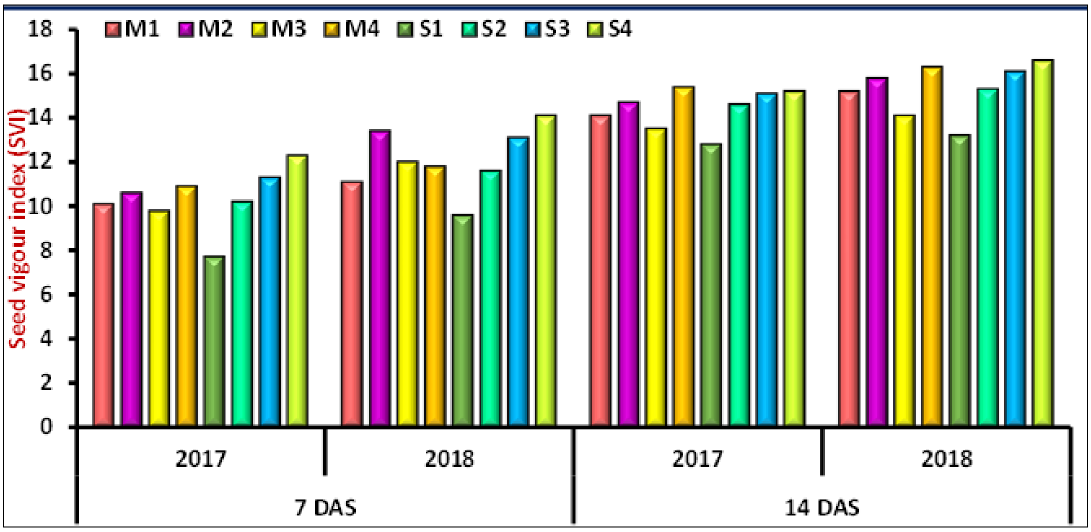

Fig 1: Seedling Vigour Index of Aerobic rice at && 14 Days after Sowing during 2017 & 2018

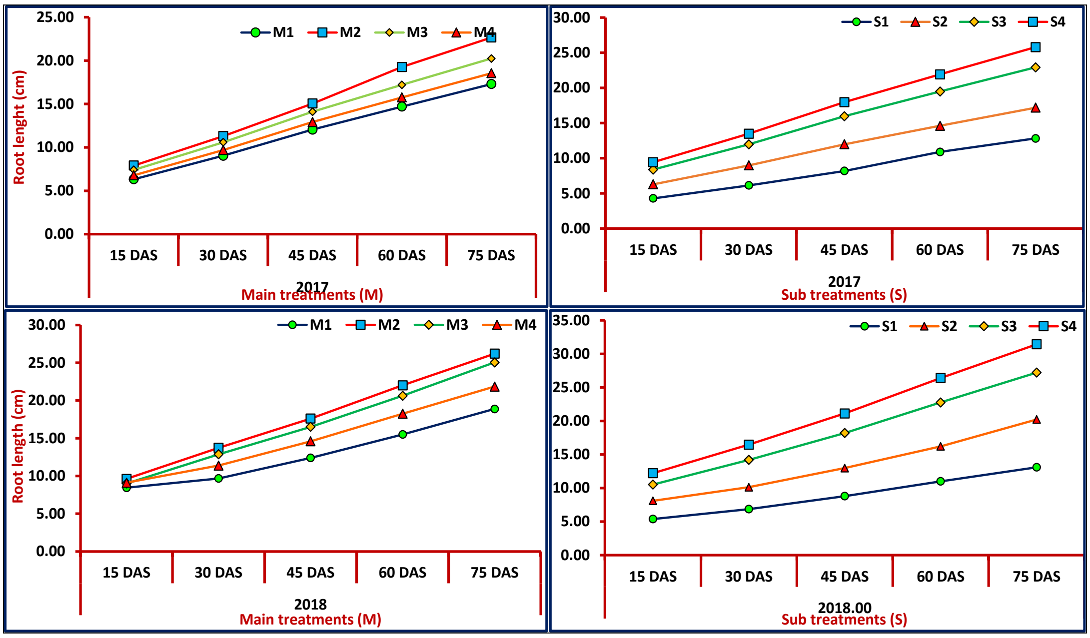

Fig 2: Root length of aerobic rice as influenced by organic nutrient sources and graded fertilizer doses during *kharif* 2017 and 2018.

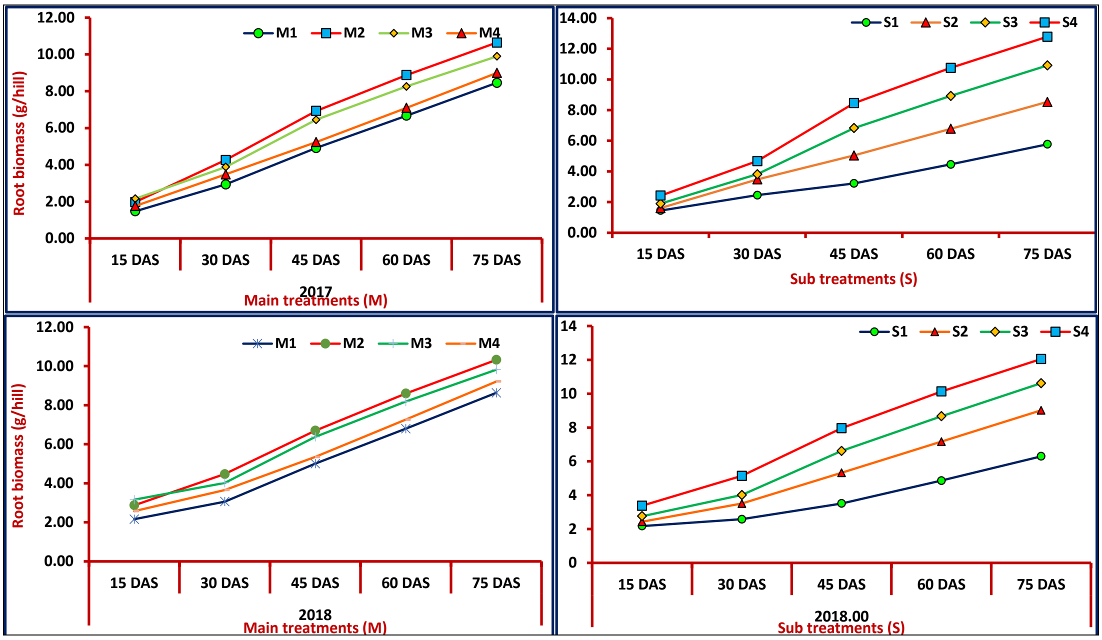

Fig 3: Root biomass of aerobic rice as influenced by organic nutrient sources and graded fertilizer doses during *kharif* 2017 and 2018.

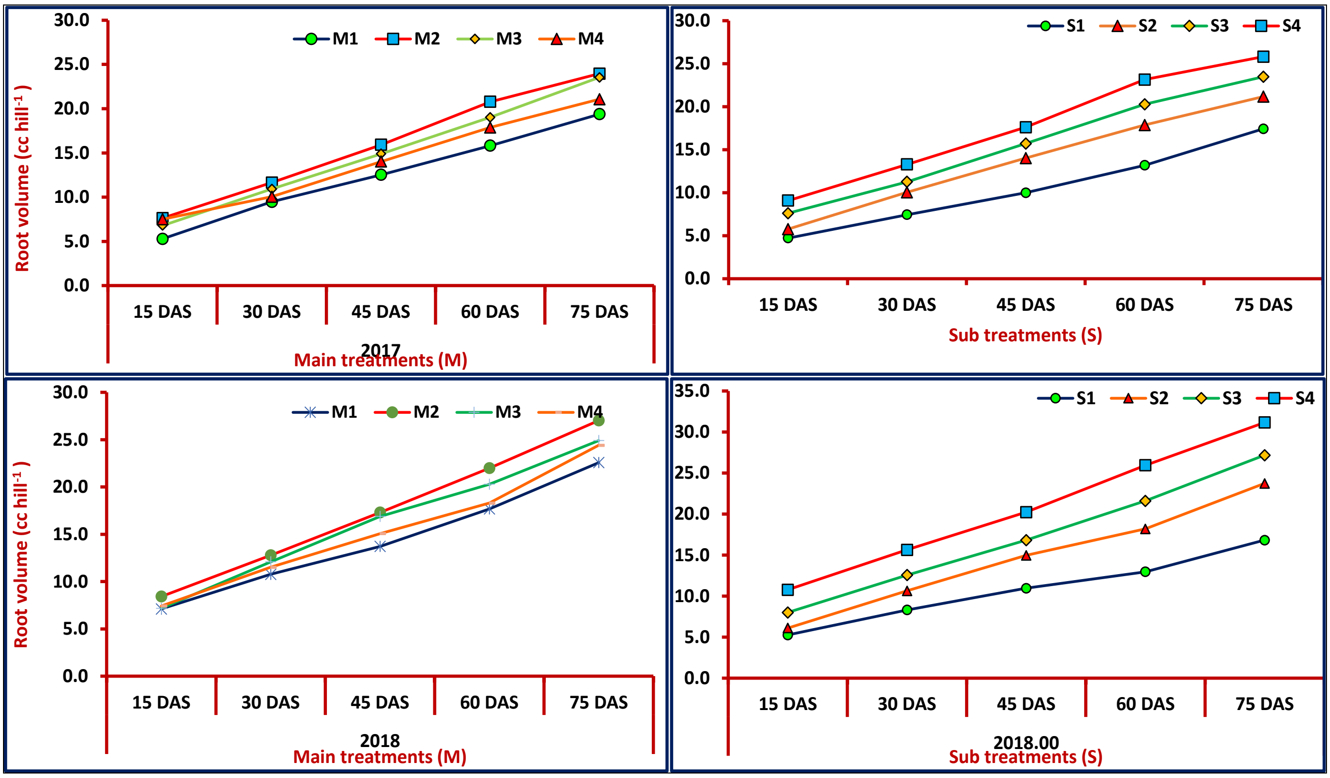

Fig 4: Root volume of aerobic rice as influenced by organic nutrient sources and graded fertilizer doses during *kharif* 2017 and 2018.

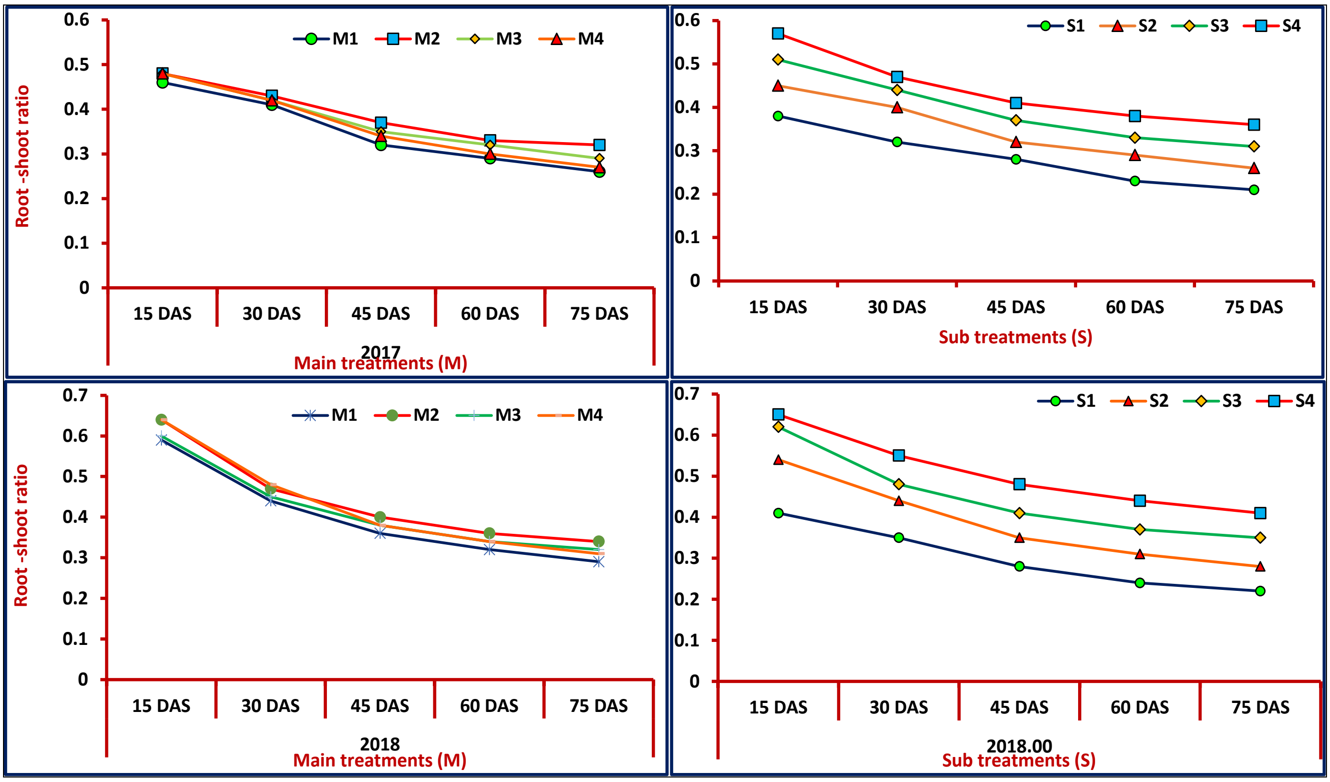

Fig 5: Root-shoot ratio of aerobic rice as influenced by organic nutrient sources and graded fertilizer doses during *kharif* 2017 and 2018.

Results and Discussions

Seedling vigor index

Seedling vigour is the ability of the plant to emerge rapidly from soil or water. It helps in better plant establishment and successful competition with weeds in all phases of seedling development from seed germination to stand establishment. Seedling vigor index as influenced by organic nutrient sources and levels at 7 DAS, 14 DAS in aerobic rice (Table 1 & Fig.1). Different organic nutrient sources used in the study did not impact significantly on seedling vigour index either at 7 or 14 DAS, while nutrient levels did not have any prominent effect on seedling vigor index, at 7 DAS, however, at 14 DAS, S_4 [100% RDF] exhibited significantly superior seedling vigour index (15.8) and lowest (13.1) was observed with control *i.e.*, S_1 [0% RDF]. Pooled mean of two years had not depict any significant interaction effect on the seedling vigour index at both intervals. The interaction effect of main and subplots on seedling vigour index was found non non-significant during both years. Higher seedling vigor index might be due to vigorous initial growth, proper development of root system and better absorption of the applied nitrogen and phosphorus with optimum nutrient levels, in aerobic rice (Thind *et al*., 2017) [15] and Ajmal (2018) [16].

Weed competitiveness: The data on weed population and weed dry biomass before herbicide application were significantly influenced by nutrient sources (Table.2). The pooled mean depicted that, initially neem leaf manure as mulch M_1, suppressed weed emergence and resulted in lower weed population (3.7 no.m^{-2}) and weed dry biomass (2.9 g). This neem leaf manure showed higher weed competitiveness over rest of the manuring treatments in the seedling stage of rice. These results are following Sreedevi *et al*., 2019 [8]. But the nutrient levels have not registered a significant impact on weed population and weed biomass. In the later stage, data on weed population and weed dry biomass at 10 days after herbicide application were not significantly influenced by either organic sources or inorganic nutrient levels. This might be due to the reason that herbicide application was a uniform weed control practice in this study irrespective of the treatments.

Root length (cm)

Organic nutrient sources and graded fertilizer doses significantly influenced the root length of aerobic rice during *kharif* 2017 and 2018 at all growth intervals *i.e.*, 30, 45, 60, and 75 DAS except at 15DAS. Root length had shown a progressive increase from 15 to 75 DAS and produced the highest root length during *kharif* 2018 as compared to 2017 presented in table2.

The two-year pooled mean results of aerobic rice revealed that at 15 DAS the organic nutrient sources did not show a significant effect on root length. However, from 30 to 75 DAS there was a noteworthy variation in root length of aerobic rice with applied organic manures. M_2 [vermicompost @ 2t ha^{-1}] produced significantly higher root length values of at 30, 45, 60 and 75 DAS which was on par with M_3 [goat manure@ 5t ha^{-1}] at all growth intervals. Among the subplots, S_4 [100% RDF] had produced the highest root length at various growth intervals, while S_1 [Control] had lowest root length 15 to 75 DAS. However, it was evident from table 1 that, the interaction effect between organic nutrient sources and graded fertilizer doses on root length of aerobic rice was found to be nonsignificant at all growth intervals during both the years.

Root biomass (g hill^{-1})

Different organic nutrient sources and graded fertilizer doses applied to aerobic rice had shown a progressive increase in root biomass from 15 to 75 DAS and the highest root biomass was recorded at 75 DAS, and higher root biomass was recorded during *kharif* 2018 compared to 2017 as presented in table 3. The two-year pooled mean results of aerobic rice revealed that M_2 [vermicompost @ 2 t ha^{-1}] produced significantly highest root biomass at 30, 45, 60 and 75 DAS, which was at par with M_3 [goat manure@ 5t ha^{-1}] at 30, 45, 60 and 75 DAS while M_4 [microbial consortium] produced comparable root biomass (2.42 g hill^{-1}) with M_2 [vermicompost @ 2 t ha^{-1}] at 15 DAS. Among subplots, S_4 [100% RDF] had produced maximum root biomass at various growth intervals, while S_1 [Control] had lowest root biomass at 15 to 75 DAS.

Root volume (cc hill^{-1})

The response of root traits to applied nutrition is indicative of its ability to remove more nutrients and water from the soil. The data about root volume as influenced by organic nutrient sources and graded fertilizer doses are given in table 4.Two-year pooled mean analysis revealed that among different organic sources of nutrients, M_2 [vermicompost @ 2 t ha^{-1}] registered maximum root volume which was, statistically at par with M_3 [goat manure @ 5 t ha^{-1}] and the minimum was observed with M_1 [neem leaf manure @ 6 t ha^{-1}].The efficacy in nutrient dose resulted in a significant enhancement in root volume of aerobic rice and the highest root volume was recorded with the application of higher nutrients 100% RDF {S_4} followed by 75% RDF{S_3} 50% RDF {S_2}and least root volume were put forth by Control {S_1}.

However, the interaction effect of organic sources nutrients and graded fertilizer doses was found non-significant on root volume.

Root-shoot ratio

The root-shoot ratio decreased progressively with the advancement of age 15, 30, 45, 60 and 75 DAS, organic nutrient source applied to aerobic rice resulted from statistically similar effect on the root -Shoot ratio at all growth intervals *i.e.*,15, 30, 45, 60 and 75 DAS during both the years of study. While with efficacy in fertilizer level, there was a significant enhancement in root-shoot ratio, S_4[100% RDF] had produced the highest root-shoot ratiowhile, S_1 [Control] had the lowest root: shoot ratio of from 15 to 75 DAS.

The interaction effect between organic nutrient sources and graded fertilizer doses on the root-shoot ratio of aerobic rice was found to be non-significant at all growth intervals during both years (Table 5).

The positive effect of nutrient management on root traits *viz;*root length, root biomass, root volume and root-shoot ratio can be attributed to the application of organic sources of nutrients like vermicompost or goat manure which enhances soil fertility and sufficiently makes available plant nutrients and other growth promoting substances during different growth stages, resulting in improved root penetration, nutrients and moisture absorption, thus accelerating meristematic cellular activity, expressing morphologically in terms of higher root growth traits as corroborated by Rajanna (2012) [17], Siddaram *et al*. (2017) [25] and Supreet *et al*. (2018) [19] and Jana *et al*. (2020) [20].

Enhanced level of nutrient application in balanced proportion stimulated the elongation of adventitious roots and increased the root length, and root volume. (Dong *et al*., 2001) [21] root biomass production and higher root-shoot ratio. Maheshwari *et al*. (2007) [22], Patil *et al.* (2013) [23] and Anil (2014) [24].

The interaction effect of different organic nutrient sources and fertilizer levels was non-significant during both the years of study.

Conclusion

From the present study it can be concluded that SVI were unaffected by different organic sources of nutrients. Among nutrient levels, 100% RDF produced significantly longer roots, higher biomass, volume and root-shoot ratio, and seedling vigor index. The neem leaf manure @ 6 t ha^{-1} applied as mulch suppressed the weed emergence and resulted in the lowest weed population and weed biomass, and exhibited higher weed competitiveness the seedling stage of rice**.** the organic sources of nutrients and graded doses of fertilizer have put forth a significant impact on root traits of aerobic rice, application of vermicompost @ 2t ha^{-1} or goat manure @ 5t among the nutrient sources and 120: 60: 40 Kg of NPK is recommended for aerobic rice under SAT.

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