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Comparative Analysis of Different Nitrogen Treatments on Yield and Its Attributes in SRI and Conventional Cultivation

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Abstract

The current study reveals the effect of inconsistent nitrogen treatments on yield and yield attributes in the System of Rice Intensification (SRI) and conventional practices when compared during *Kharif* 2018 and 2019. Growth parameters like plant height, tillers per plant, yield attributes *viz;* length of panicle, number of filled and unfilled grains per panicle, test weight, straw yield, and harvest index were compared under both conventional and SRI methods. Subplots comprising four nitrogen management practices like control (N_1), 100% organic (N_2), 50% organic+50% inorganic (N_3) 100% inorganic (N_4) were taken. The maximal yield was recorded in SRI (5265 kg ha^{-1}) than conventional cultivation i.e., Normal Transplanting (4168 kg ha^{-1}). Among the nitrogen management practices 50% inorganic + 50% organic treatments (N_3) showed better performance when compared to 100% inorganic (N_4), followed by 100% organic (N_2) and control (N_1). The pooled analysis of grain yield was observed to be highest in the N_3 treatment (5551 kg ha^{-1}), followed by N_4 (5185 kg ha^{-1}), N_2 (4988 kg ha^{-1}), and control N_1 (3142 kg ha^{-1}). A similar pattern was also seen pertaining to the yield attributes.

Keywords: Rice, SRI, Conventional, Nitrogen management, Organic and inorganic.

Introduction

Rice *(Oryza sativa* L.*)* is an ancient crop cultivated in 117 nations worldwide and hence named "global grain". It is by far the oldest domesticated crop known to humankind. Rice is always an important crop and a good source of energy for over one-third of the world's citizenry. India has a productivity of 2.7 tons per hectare over an area of 45 million hectares with a production of 123.7 million tons (CMIE, 2021). Rice production currently faces constraints like declining net cultivable land, lowering the water table, and other climate change issues like increasing temperature, carbon sequestration, and methane emission that are causing a decline in yields. Water is a restraining factor in rice grain production**.** Future predictions of the scarcity of water limiting agricultural production estimated that by 2025 about 15-20m ha^{-1}in Asia's grain fields will suffer from the water shortage in drought season. Especially 45 to 90% of the freshwater is used for irrigating total agricultural crops (Tuong and Bouman, 2003).

The conventional method is the most important and common practice of crop establishment methods under irrigated lowland rice, which not only consumes extra water but also results in water wastage and subsequently results in the degradation of land. To overcome this problem, many techniques evolved and amongst them is the System of Rice Intensification (SRI). This technique has emerged as an aqua-saving technology that has shown enhanced yield with a controlled supply of water. SRI system has been documented to produce higher rice grain yields with less irrigation and without the need for costly improved seeds or expensive chemical fertilisers. This additional extended rice will have to be produced on much less land with less water usage, labour and chemicals (Zheng *et al*., 2004). The combined use of organic and inorganic fertilizers helps in maintaining yield stability in addition to improving soil physicochemical and biological properties. Among the nutrients, nitrogen is crucial and limiting element in rice growth (Jayanthi *et al*., 2007).

Materials and Methods

The field experiments were carried out during *kharif* 2018 and 2019 at ICRISAT farm Patancheru, Hyderabad, Telangana, India. The geographic site of the farm is at 17°53'N latitude, 78°27'E longitude, and 545 m altitude above mean sea level. The experimental soil was clay loam black, neutral in reaction (pH 6.98) with non-saline (EC 0.692 d/Sm^{-1}). The experimental soil contains 1.004 % high organic carbon, 202 kg ha^{-1} of available Nitrogen, 40 kg ha^{-1} of available Phosphorus and 305 kg ha^{-1} of available Potassium. Akshayadhan (DRR Dhan 35), a high yielding, resistant-to-blast, semi-dwarf rice variety with a duration of 135 days and yield potential of 5.5t ha^{-1} was selected for the present study.

The experiment was carried out in split plot design with two main plots consisting of two establishment methods of cultivation, *i.e.,* System of Rice Intensification (SRI) and Normal Transplanting (NTP). The subplots comprising of four nitrogen management practices, *viz.,* control (N_1), 100% organic (N_2), 50% organic + 50% inorganic (N_3), 100% inorganic (N_4). The total subplot treatments sum up to 12 treatment combinations and 3 replicates. The experimental field was provided with irrigation channels and the discrete plots were demarcated by bunds in both methods. The recommended fertilizer doses 120:60:40 Kg ha^{-1} of N: P_2O_5: K_2O were applied as single super phosphate (SSP) and muriate of potash (MOP). Nitrogen was applied in the form of urea in three equal splits, half as basal, one-fourth at maximum tillering and one-fourth at panicle initiation stage in all the treatments of 100% inorganic treatment.

During flowering stage, three plants from each treatment were selected randomly and plant height was measured from base to flag leaf. The number of tillers per plant was also recorded. Ten panicles were selected to record the panicle length randomly. It was measured from the base of the primary rachis to top most spikelet and the average length was expressed in centimetres (cm).

After counting the filled and chaffy grains of a single panicle, the filled grain percentage and spikelet sterility percentage were determined with the following formula:

Filled grain percentage = (Number of filled grains/ Total number of grains) x 100

Spikelet sterility percentage = (Number of unfilled grains /Total number of grains) x100

Test weight was calculated by weighing a thousand grains obtained from three randomly selected hills and denoted in grams (g).

Plants in the net plot area were harvested separately in every plot, seeds separated after threshing and cleaning followed by drying under sunlight and the grain yield per plot was recorded, computed and expressed as kg ha^{-1}.

Results and Discussion

The plant height was significantly high in SRI (105,106 and 106.1cm during 2018, 2019 and pooled means, respectively) over NTP (99, 98 and 99.1 cm during 2018, 2019 and pooled means, respectively). Plant height was superior in the SRI method when compared to the conventional method of rice cultivation (Uphoff, 1999). Among the nitrogen treatments, maximum plant height was attained with 50% organic + 50 %, inorganic (N_3) (109,111 and 110.8 cm during 2018, 2019 and pooled means, respectively) followed by 100% Inorganic (N_4) and 100% Organic (N_2) treatments (**Table 1**). The lowest plant height was found in control (N_1) (93, 92 and 93.5 cm during 2018, 2019 and pooled means, respectively). The treatment with SRI practice was with higher plant height mainly because of wider spacing between rice plants, which allows the plant to get more light, nutrients and air. Usage of organic + inorganic nitrogen gives a better plant growth response than inorganic fertilizers due to the more sustained supply of nutrients by the favourable growth of soil biota. Satynarayana *et al*., (2007) reported similar results.

The number of tillers was significantly high in the SRI (396, 411 and 403 m^{-2} in 2018, 2019 and pooled means, respectively) over NTP (336,346 and 341 m^{-2} in 2018, 2019 and pooled means, respectively) (**Table 1**). This may be due to the SRI cropping strategy, shorter length of phyllocorns and enhanced tillering. Mulu (2004) also reported similar results. In nitrogen treatments, the maximum tiller number (464, 461 and 462 in 2018, 2019, and pooled, respectively) was attained with 50% organic +50 % inorganic (N_3) nitrogen treatment. This was followed by 100% Inorganic (N_4) and 100% Organic (N_2) treatments. All the treatments were significantly superior to the control (N_1) during the two years of study. The lowest tiller number was found in control (N_1) (256, 262 and 259 m^{-2} in 2018, 2019 and pooled means, respectively). However, the interactions between main plots and subplots were not-significant. There is a continuous supply nutrient throughout the crop growth period in 50% organic +50% inorganic (N_3). Gopalakrishnan *et al.*, (2013) also reported that tillers in SRI-cultivated plants were higher when compared to the conventional method. The reasons for higher tiller density in SRI could be that the younger seedlings having higher vigour to produce more tillers and an additional number of days, even a radically reduced number of plants can produce more tillers per unit area. This was complemented by low competition between plant-to-plant and soil churning by cono weeder has a specific positive effect on the tillering in SRI.

Table 1. Plant height and number of tillers as influenced by planting methods and nitrogen treatments

Treatments	Plant height (cm)			No. of tillers (m^2)		
	2018	2019	Pooled	2018	2019	Pooled
Mean values of main treatments (M)						
M1-System of rice Intensification (SRI)	105	106	106.1	396	411	403
M2-Normal Transplantation (NTP)	99	98	99.1	336	346	341
S.Em±	0.4	0.9	0.62	4.3	5.9	3.07
C.D at 5%	2.7	5.9	4.06	28.3	38.9	20.1
Mean values of sub treatments						
N_1-Control	93	92	93.5	256	262	259.1
N_2-100% Organic	100	100	100.5	352	378	365.3
N_3-50% Organic + 50% Inorganic	109	111	110.8	464	461	462.6
N_4-100% Inorganic	106	105	105.8	392	413	402.6
S.Em±	0.7	0.7	0.56	9.2	10.8	8.6
C.D at 5%	2.2	2.3	1.76	28.6	33.7	27

Panicle length was also significantly higher in SRI (27.1, 27.2, and 27.1cm in 2018, 2019 and pooled, respectively) as compared to NTP (22.4, 22.9 and 22.6 cm and pooled, respectively). The observed panicle length in SRI when compared with normal method reached 19%. It was associated with various phenotypical alterations such as longer panicles, more open plant architecture with more erect and larger leaves, more light interception, high leaf chlorophyll content at the ripening stage, delayed senescence, higher photosynthesis rate and lower transpiration (Thakur *et al*., 2009). The higher value of panicle length was observed in N_3 (29.8 cm) followed by N_4 (26.9cm), N_2 (23.4 cm) and N_1 (**Table 2**) Application of organic and inorganic nitrogen supply 50% organic+50% inorganic (N_3) nitrogen treatment results in continuous supply of nutrients throughout the growth period of the crop (Damodaran *et al.*, 2012). These characteristics were associated with longer panicle length with greater number of grains and with enhanced grain filling in widely spaced hills compared with closely spaced hills. Similar results were also reported earlier by Latif *et al.*, (2005) and Menete *et al.*, (2008).

Establishment methods influenced the test weight of rice significantly with the highest in SRI (22.1, 21.7 and 21.9g in 2018, 2019 and pooled, respectively) as compared to NTP (19.7,18.9 and 19.3g in 2018, 2019 and pooled, respectively). This might be due to alternate wetting and drying (AWD) with wider spacing that promotes more profuse growth of roots and tillers, and more space (below and aboveground) per hill for access to nutrients, water and light. These changes improved the root growth and function with open canopy structure and prolonged leaf greenness, light utilization for higher photosynthetic rates during reproductive and grain filling stages. Due to this, a higher number of panicles and the number of grains per panicle, and lower spikelet sterility are easily noticeable. Significant variation was observed in test weight due to the nitrogen treatments. The higher average value of test weight was seen in N_3 (24.8 and 24.1g during 2018 and 2019, respectively) followed by N_4 and N_2. The minimal test weight was recorded in N_1 (16.1 and 16.5g during 2018 and 2019, respectively). Higher test weight in N_3 treatment was recorded in the present investigation due to the nitrification process by bacteria which increases nitrogen availability. Kronzucker *et al*., (1999), also reported similar results.

Table 2. Panicle length and test weight influenced by planting methods and nitrogen treatments

Treatments	Panicle length (cm)			Test weight (g)		
	2018	2019	pooled	2018	2019	Pooled
Mean values of main treatments (M)						
M1-System of rice Intensification (SRI)	27.1	27.2	27.1	22.1	21.7	22.1
M2-Normal Transplantation (NTP)	22.4	22.9	22.6	19.7	18.9	19.3
C.D at 5%	1.48	0.86	1.13	1.29	2.00	0.82
Mean values of sub treatments						
N_1-Control	19.2	19.5	19.4	16.1	16.5	16.3
N_2-100% Organic	23.2	23.6	23.4	20.5	19.6	20.0
N_3-50% Organic + 50% Inorganic	29.5	30.1	29.8	24.8	24.1	24.5
N_4-100% Inorganic	27.0	26.9	26.9	22.3	21.0	21.6
C.D at 5%	1.73	1.14	0.91	1.43	1.29	0.91
TXM	NS	NS	0.28	NS	NS	NS
MXT	NS	NS	0.87	NS	NS	NS

There was a remarkable effect of the method of establishment on grain filling percentage of rice, during both the years of study. A higher percentage of grain filling was recorded in SRI (179.8 and 179.9 %) compared to NTP in 2018 and 2019, respectively (**Table 3**). This was because of recommended management practices during the early ripening stage, higher biomass production in SRI as supported by more leaf area, longer length of panicles and more grains which was a major source of carbohydrate production. This positively improved the grain filling percentage in SRI. These results are in corroboration of the findings of Thakur *et al.*, (2013). Application of nitrogen through N_3 treatment recorded significantly higher percentage of grain filling over other nitrogen treatments during both the years of study. In $N_{3,}$ the percentage of grain filling was significantly maximum, 180.8 and 182 g during 2018 and 2019, respectively compared to N_4 and N_2. The minimal test weight was recorded in the N_1 treatment (Control). Split application of Nitrogen through 50% Inorganic + 50% Organic increases available nitrogen to the crop, thus providing better nitrogen uptake and a greater number of filled grains panicle lead to greater dry-matter production and its translocation to sink. Prabhakarsetty *et al*., (2007) also reported similar results.

The SRI method registered a significantly lower percentage of spikelet sterility (5.5 and 6.0%) as compared to NTP (10.5 and 10.5 %) during 2018 and 2019, respectively. The possible reason could be higher photosynthetic rates and lower inter and intra-tiller competition and wider spacing during dry matter integration under NTP. Rajendran *et al*., (2013) have supported these results. Application of nitrogen through treatment N_3 recorded a significantly lower percentage of spikelet sterility (5.1 and 5.3%) compared with other nitrogen treatments. The N_1 treatment registered a higher percentage of spikelet sterility (11.6 and 12.5%) during 2018, 2019 and in pooled means, respectively (**Table 3**). Application and combination of organic manures, besides supplying essential nutrients, will add to the favourable conditions for soil microbes by being the source of carbon for them, sustained the plants green even at the time of maturity. Hence, the contribution of carbohydrates from the current photosynthetic activity and the efficient translocation into the grain has resulted in an increased number of filled grains and reduced the unfilled grains per panicle. These results were in agreement with Wijebandara *et al.,* (2009).

Table 3. Influence of planting methods and nitrogen treatments on grain filling and spikelet sterility

Treatments	Grain filling (%)			Spikelet sterility (%)		
	2018	2019	pooled	2018	2019	Pooled
Mean values of main treatments (M)						
M1-System of rice Intensification (SRI)	179.8	179.9	182.4	5.5	6.0	6.0
M2-Normal Transplatation (NTP)	145.5	144.3	148.5	10.5	10.5	10.9
S.Em±	0.2	0.3	0.4	0.5	0.1	0.3
C.D at 5%	1.7	2.1	3.0	3.2	1.0	2.3
Mean values of sub treatments						
N_1-Control	143.8	142.5	147.1	11.6	12.5	12.3
N_2-100% Organic	156.3	157.1	158.8	8.1	8.3	8.6
N_3-50% Organic + 50% Inorganic	180.8	182.0	183.3	5.1	5.3	5.6
N_4-100% Inorganic	169.8	166.8	172.6	7.1	7.0	7.3
S.Em±	1.4	1.3	0.98	0.3	0.2	0.2
C.D at 5%	4.3	4.0	3.06	1.0	0.8	0.8
TXM	NS	NS	NS	NS	NS	NS
MXT	NS	NS	NS	NS	NS	NS

There was a significant increase in per cent grain yield in SRI was 28.1, 24.5 and 26.3over NTP during 2018, 2019 and their pooled means, respectively (**Table 4**). System of rice intensification creates a different environment for the rice plant's favourable growth such as physiological functioning, better soil aeration, wider spacing and less competition for higher root growth. Soil environment plays a major role in root activity, and nutrient availability, capturing all the essential nutrient elements important for all plant growth and thereby leading to higher tillering and more dry matter production as reported by Thigyarajan *et al.,*(2002). The influence of SRI biological and nutrient dynamics appears to enhance the response to higher grain yield of plants.

Yield attributes such as reduced intra-hill competition favoured the development of more lateral roots and root growth. Grain yield in rice was determined by the number of panicles per unit area, panicle length, filled grains per panicle and panicle weight, which were observed to be higher in SRI method than NTP. which was responsible for the increased grain. Based on nitrogen application, 50% organic +50% inorganic (N_3) treatment was found to have significantly greater grain yield during both years of study. The grain yield of rice is highest in 50% organic + 50%

inorganic (N_3) (5547, 5554and 5551 kg ha^{-1}) followed by 100% inorganic (N_4) (5128, 5242 and 5185 kg ha^{-1}) and 100% organic (N_2) (4974, 5002 and 4988 kg ha^{-1}) treatments, respectively. The lowest grain yield observed in Control (N_1) (3094, 3189 and 3142 kg ha^{-1}).

The higher availability of nitrogen in 50% organic + 50% inorganic (N_3) treatment resulted in higher grain yields as higher availability of nitrogen determined integration of chlorophyll molecule, lead to corresponding optimization of photosynthetic activity and photosynthetic assimilates. These conditions enhance the effective root oxidizing activity higher and better root distribution in the soil, more perpendicular and larger leaves, more light interference high chlorophyll content because of longer panicles, higher grain filling and finally improve the grain yield (Thakur *et al.,* 2009).

The Straw yield of rice was significantly higher in SRI (5884 and 5787 kg ha^{-1}) than in NTP (4936 and 4872 kg ha^{-1}) in 2018 and 2019, respectively. It could be because of more dry matter production, and more grain weight per unit nutrient taken up. SRI root system absorbs more nutrients from the soil and then supplies them to the plant. There is delayed senescence and the higher LAI (Leaf Area Index) presents higher nitrogen in the leaves after flowering in SRI plants compared to the NTP planting method (Mahender Kumar *et al.*, 2009). Application of nitrogen based on N_3 treatment had shown significantly higher straw yield (6119 and 6069 kg ha^{-1} during 2018 and 2019, respectively). N_4 treatment was statistically at par with N_3 but these nitrogen treatments were significantly superior to N_2 treatment. This might be because of an adequate supply of nitrogen throughout the crop growth period that led to higher dry matter production (Alam *et al.*, 2013). N_1 treatment recorded lower straw yield (3928 and 3845 kg ha^{-1} during 2018 and 2019 respectively).

The harvest index of rice was not significantly different among the planting methods and nitrogen treatments, and also the interaction effect during the two years of study (**Table 4**) Significant difference was however observed among pooled means observed in SRI (47.2%) compared to NTP (45.7%). The maximum harvest index was observed in N_3 (47.6%) and the lowest was recorded in N_1 (44.6%). Increased

Table 4. Grain yield, straw yield and harvest Index (%) influenced by planting methods and nitrogen treatments in rice

Treatments	Grain yield(kg/ha^{-1})			Straw yield(kg/ha^{-1})			Harvest index(%)		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
Mean values of main treatments (M)									
M_1	5264	5266	5265	5884	5787	5836	47.0	47.4	47.2
M_2	4107	4228	4168	4936	4872	4904	45.1	46.3	45.7
S.Em±	21.3	32.9	17.7	38.1	13.7	12.4	0.27	0.24	0.08
C.D.5%	139.9	215	116.5	249.7	90.2	81.8	1.80	NS	0.57
Mean values of subtreatments (N)									
N_1	3094	3189	3142	3928	3845	3887	43.9	45.3	44.6
N_2	4974	5002	4988	5689	5544	5617	46.4	47.3	46.8
N_3	5547	5554	5551	6119	6069	6094	47.5	47.8	47.6
N_4	5128	5242	5185	5904	5860	5882	46.4	47.1	46.7
S.Em±	53.6	40	25.7	91	99.8	61.7	0.51	0.49	0.25
C.D.5%	167.2	124.8	80.2	283	311	192	1.6	1.5	0.79
TXM	NS	NS	NS	NS	NS	NS	NS	NS	NS
TXM	NS	NS	NS	NS	NS	NS	NS	NS	NS

harvest index in the SRI system and N_3 treatment (50% Organic + 50% Inorganic) has shown that perhaps even a radically lesser number of plants can produce more tillers per unit area, and the panicles usually have more number of grains, total dry matter production, grain and yield parameters (**Figure 1**).

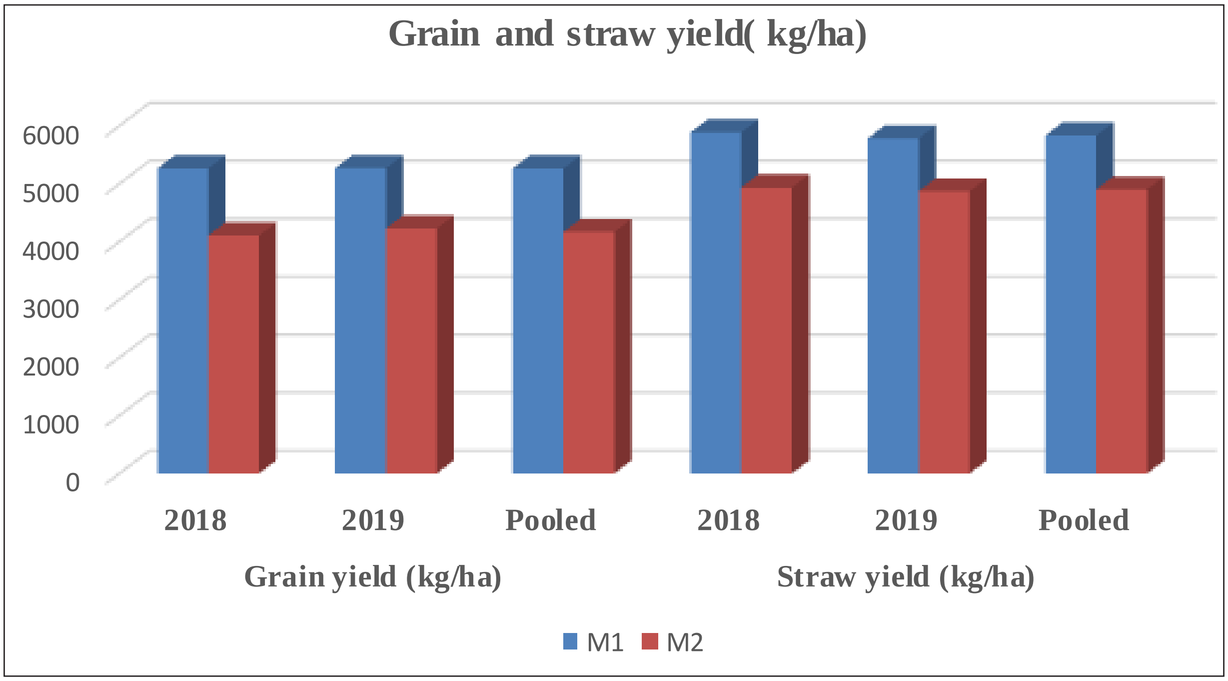

Figure1. Grain yield, and Straw yield influenced by planting methods and nitrogen treatments in rice

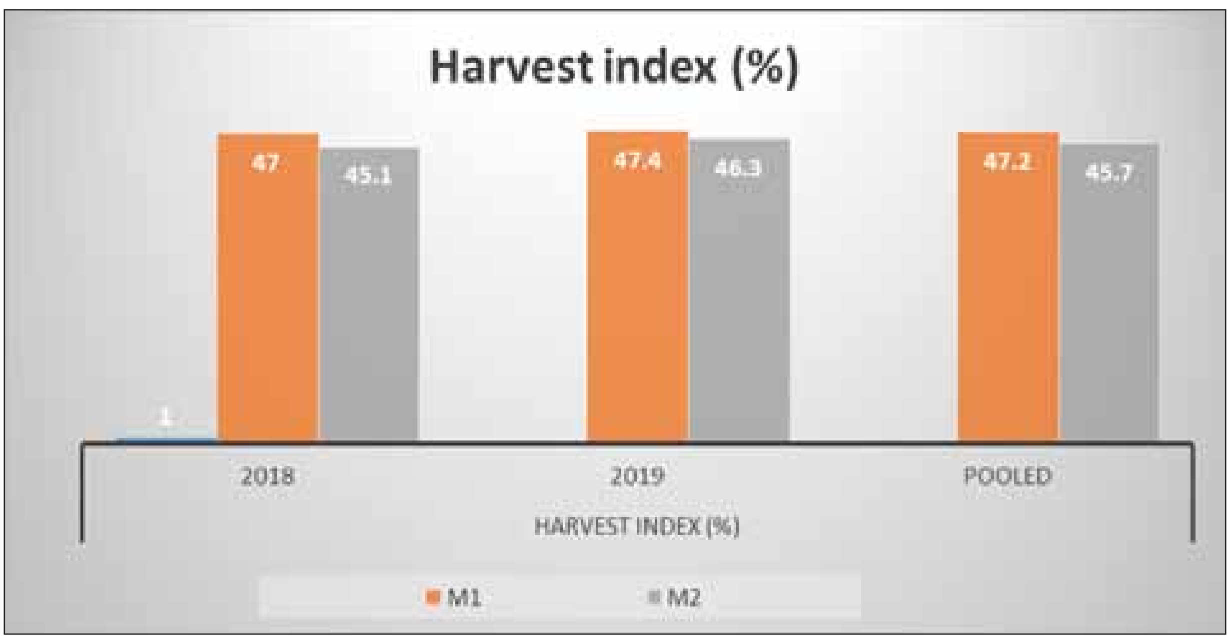

Figure 2. Harvest index influenced by planting methods and nitrogen treatments in rice

Conclusion

SRI showed significantly higher yield parameters like the number of tillers, panicle length, grain weight, and the number of grains per panicle. Therefore, there is a significant grain yield increase of 24.6% under SRI over NTP. Treatment 50% organic + 50% Inorganic has shown an increased percentage of filled grains and test weight compared to other treatments. Among the nitrogen treatments, 50% organic + 50% Inorganic showed 76.0% enhanced yield over control in both the years of pooled means. From the above results, it can be concluded that the SRI method was more promising than NTP and treatment with 50% organic + 50% inorganic was found promising over the other nitrogen treatments.

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