



Enhancing rice productivity in sodic soils of Indo-gangetic plains through improved nursery management practices

YASH PAL SINGH*, VINAY K MISHRA, DHANANJAY SINGH and RAVINDRA K GUPTA

ICAR-Central Soil Salinity Research Institute, Lucknow, Uttar Pradesh 226 002, India

Received: 12 July 2019; Accepted: 02 September 2019

ABSTRACT

The management practices for rice cultivation in salt-affected soils are obviously different than those in normal soils and for a short duration variety than those of a medium to long duration variety. Hence, experiment was planned and conducted at Central Soil Salinity Research Institute (CSSRI), Regional Research Station, Lucknow, Uttar Pradesh, India during 2011-12 to 2013-14 (*kharif*) hypothesizing that the combination of improved nursery management practices and high yielding salt tolerant variety would enhance productivity and profitability of rice in sodic soils. The results revealed that, improved nursery management practices like lower seed density, combined application of organic amendments and inorganic fertilizers in the seed bed (5 t/ha farmyard manures (FYM) followed by 100-50-50 kg N-P₂O₅-K₂O) and optimum age of seedlings enhanced seedling growth (shoot and root length, number of leaves, leaf area and dry matter) resulting higher grain yield and minimized production cost. Thirty-d-old seedling of salt tolerant variety CSR 36 raised using improved nursery management practices yielded 8.4% and 4.0% higher over 25 and 40d-old seedlings respectively. Salt-tolerant variety CSR 36 grown with improved nursery management options and followed by recommended dose of fertilizers (150-60-40-25 kg N-P₂O₅-K₂O-ZnSO₄/ha) in main field, could produce significantly higher grain yield than the yield level achieved using prevailing nursery management practices. This approach of combining cost effective nursery management and crop establishment options for salt-tolerant varieties can maximize the productivity and profitability of sodic lands in Indo-Gangetic alluvial plains.

Key words: Age of seedling, Benefit:cost ratio, Nutrient management, Seed density, Salt tolerant variety

Salt-affected soils are one of the major abiotic stresses that adversely affect the overall metabolic activities and cause plant demise. The global extent of salt-affected area is about 955×10^6 ha, affecting about 7% of the world's total land area. Indo-Gangetic Plain region in India lies between 21° 55' to 32° 39' N and 73° 45' to 80° 25' E having about 2.73 million ha salt-affected soils (Mandal *et al.* 2009). Due to high pH (>8.5), high exchangeable sodium percentage (ESP) (>15%), and high concentration of soluble salts these soils have poor physical conditions. Besides, these soils are poor in organic carbon (<0.1%), and available N. The N requirement in sodic soils is relatively higher because of higher N losses through volatilization and salt tolerant varieties responded positively to higher N doses (Singh *et al.* 2008, Wong *et al.* 2010).

In Indo-Gangetic plain region, rice (*Oryza sativa* L.) is the only option available to farmers as it has potential to counter sodicity in a better way than the other crops (Panigrahy *et al.* 2010). The productivity of rice in sodic

soils is much below (<2.0 t/ha) the potential level because of sodicity stress, use of traditional varieties, high mortality and adoption of poor management practices in the nursery as well as main field (Singh *et al.* 2016a). Generally, farmers have been seen to raise rice nursery with higher seed rates (60-80 kg/ha), poor and imbalance nutrient management and transplant younger seedlings resulting poor seedling with consequent yield losses. Adequate nutrition to nursery is an important factor to get healthy rice seedling (Sarwar *et al.* 2011). Integration of farmyard manure (FYM) with inorganic fertilizers was reported to be effective for raising healthy nursery (Sarangi *et al.* 2015, Singh *et al.* 2018). Age of seedlings is one of the important factors that determine the crop growth, number of tillers per hill and yield attributing characters (Adhikari *et al.* 2013). Hence, to develop improved nursery management practices for higher productivity and profitability of salt tolerant variety in sodic soils of Indo-gangetic plains it was imperative to conduct this study.

MATERIALS AND METHODS

Field experiment was conducted for three years (2011-12 to 2013-14) at the experimental farm of ICAR-CSSRI, Regional Research Station, Uttar Pradesh, India (26° 47'

*Corresponding author e-mail: ypsingh.agro@gmail.com

58° N, 80° 46' 24"E and 120 m above MSL). The study site representing large area of abandoned alkali soils of Indo-Gangetic plains. The climate is semi-arid, subtropical and monsoonic receiving an average annual rainfall of 817mm). The mean maximum and minimum temperature during the cropping period (July-October) was 33.5°C in July and 18.8°C in October respectively. Field experiment consisting of two seed densities (D_1 : 25 g and D_2 : 40 g/m²) as main plot, five fertilizer levels of N-P₂O₅-K₂O kg/ha (N_1 : 50-0-0 (25 kg N through 5 t/ha FYM and 25 kg N through chemical fertilizer- farmers practice), N_2 : 50-50-50 (25 kg N through 5 t/ha FYM and 25 kg N, full P and K through chemical fertilizer), N_3 : 75-50-50 (25 kg N through 5 t/ha FYM and 50 kg N, full P and K through chemical fertilizer), N_4 : 100-50-50 (25 kg N through 5 t/ha FYM and 75 kg N, full P and K through chemical fertilizer), and N_5 : 125-50-50 (25 kg N through 5 t/ha FYM and 100 kg N, full P and K through chemical fertilizer) as sub-plot and four ages of seedlings (T_1 : 25 days, T_2 : 30 days, T_3 : 35 days and T_4 : 40 days) as sub-sub-plot treatments was conducted with three replications in a split-split plot design. Uniform quantity of FYM @ 5 t/ha was applied in all the treatments before nursery sowing. Basal application consisted of 50% N and full dose of P₂O₅ and K₂O, and the rest of N was applied in two equal splits 12 and 22 days after sowing. Before sowing, seed was soaked for 24 h. The sprouted seeds were sown at 5 days interval so that the transplanting could be done on the same day. In the main field, a uniform dose of 150:60:40:25 kg/ha (N-P₂O₅-K₂O-ZnSO₄.7H₂O) was applied in all treatments. Half the N and full P₂O₅, K₂O and ZnSO₄.7H₂O were applied as basal, and the remaining N was applied in equal splits at tillering and panicle initiation stages. Before initiating the experiment, soil samples collected from 0-15cm soil depth were air dried ground and passed through a 2.0 mm sieve. The pH and EC of the soil determined in 1:2 soil: water suspension using digital pH and conductivity meters (Jackson 1967) were 9.23 and 0.61 dS/m respectively. Organic carbon determined using the rapid titration method modified by Walkley (1947) was 0.29%, and exchangeable sodium percentage 30.60, the Na⁺ and K⁺ measured by Flame Photometer were 4.50 and 0.06 meq/l, carbonate and bi-carbonates contents determined by titration with 0.01 N H₂SO₄ using phenolphthalein and methyl orange (Tandon 1995) were 1.00 and 4.00 meq/l, respectively.

To measure seedling growth, five plants were selected randomly from each treatment and uprooted before transplanting. Shoot and root length, dry weight, number and area of green leaves per seedling were recorded at the time of uprooting. The seedling vigor index (SVI) was calculated at the time of uprooting using the formula: SVI = seedling length (root + shoot) × % germination. To count number of hills/m² in main field, a quadrat of 1m² was used at three places in each treatment. Ten plants were tagged in each treatment and all growth parameters and yield attributing characters were measured from these tagged plants at maturity. Plant height was measured from

the base of the stem to the tip of the longest panicle at maturity. Days to maturity were determined when 80% of the spikelet's within each treatment had turned yellowish. After sun drying, 1000 grain weight and harvest index were computed. Grain yield was recorded from the net plot area of 20 m². Grain moisture content was determined with a micro computer digital grain moisture meter and the grain weight was adjusted to a moisture content of 14%.

All the data were subjected to analysis of variance (ANOVA) (Gomez and Gomez 1984) using WINDOSTAT statistical package. The least significant difference (LSD) at 5% probability was used to compare treatment means. The cost economics includes production cost (fixed and variable), gross return, net return and benefit/cost ratio were calculated following the methodology proposed by Kuthe (2012).

RESULTS AND DISCUSSION

Shoot and root lengths with low seeding density (25 g/m²) were 2% and 7% higher respectively than the high seeding density (40 g/m²) (Table 1). Number of leaves and leaf area/seedling with D_1 seeding density were 10.4% and 14.3% higher respectively over the D_2 seeding density (mentioned D_2). This may be due to less competition for nutrients and light with low seeding density. Shoot and root dry weight/seedling did not show a significant difference under both seed densities. The integrated use of organic and inorganic fertilizers in nursery produced healthy and vigorous plants. Application of fertilizers in the form of treatment N_5 as well as N_4 produced significantly higher root and shoot length, number of leaves, leaf area, and root and shoot dry weight compared with N_1 , N_2 and N_3 fertilizer treatments. Seedling height increased with increasing fertilizer levels (Table 1). Accumulation of more biomass and increased seedling height due to higher fertility levels reflect higher photosynthates accumulation in rice plants. Shoot and root length, number of leaves/seedling, and shoot and root dry weight/seedling were highest with T_4 (40 days old seedling) (Table 1). Seedling vigor index (SVI) was recorded higher (3767) with low than high seed density. Maximum SVI (4334) was recorded with N_5 however it was statistically at par with treatment N_4 (4287). Fourty days old seedlings had a higher vigor index than 25-days, 30-days and 35-days old seedlings but the difference between 35 and 40 days old seedlings was statistically not significant (Table 1).

There was no significant difference in plant height due to seed density and nitrogen levels but it was significantly affected by seedling age (Table 2). The nursery raised with low seed density (D_1) produced 3.4%, 9.4% and 3.1% higher productive tillers/hill, grains/panicle and panicle weight, respectively over high seed density (D_2) treatment. Sarwar *et al.* (2011) has also reported an increase in productive tillers with low seeding density. 1000-grain weight was higher in D_2 seed density treatment but the differences between D_1 and D_2 were not statistically significant. There was also a non-significant difference in

Table 1 Effect of seeding density, nutrient levels and seedling age on seedling growth

Treatment	Seedling height (cm)	Root length (cm)	Leaves/seedling	Leaf area (cm ² /seedling)	Shoot dry weight/seedling (g)	Root dry weight/seedling (g)	SVI
<i>Seeding density (g/m²)</i>							
D ₁ -25	28.21	12.32	5.11	41.4	1.49	0.36	3767
D ₂ -40	27.70	11.44	4.64	36.2	1.44	0.35	3636
LSD _{0.05}	ns ^a	0.36	0.24	1.35	ns	ns	113.2
<i>Nutrient levels (kg N-P₂O₅-K₂O/ ha)</i>							
N ₁ -25-0-0	21.34	8.62	4.30	34.2	0.99	0.20	2781
N ₂ -50-50-50	23.50	9.21	4.43	36.4	1.13	0.35	3041
N ₃ -75-50-50	29.13	10.33	4.95	41.2	1.34	0.37	3664
N ₄ -100-50-50	34.91	11.26	5.90	43.3	2.41	0.50	4287
N ₅ -125-50-50	35.25	11.40	5.86	42.6	2.63	0.58	4334
LSD _{0.05}	1.23	0.50	0.42	1.43	0.35	0.16	212.4
<i>Seedling age</i>							
T ₁ -25days	22.80	9.30	4.10	38.6	1.14	0.26	2985
T ₂ -30days	26.55	11.25	4.25	42.5	1.45	0.28	3506
T ₃ -35days	29.51	12.44	4.88	41.3	2.24	0.36	3897
T ₄ -40days	31.23	12.61	5.24	41.2	2.60	0.43	4073
LSD _{0.05}	4.6	0.56	0.26	1.24	0.23	0.12	372.4

^ans, non-significant

Table 2 Effect of seed density, nutrient management and seedling age on yield attributing characters and yields

Treatment	Productive tillers/ hill	Panicle length (cm)	Grains/ panicle	Panicle weight (g)	1000 grain weight (g)	Grain yield (t/ ha)	Straw yield (t/ ha)	Harvest index (%)	BCR ^b
<i>Seeding density(g/m²)</i>									
D ₁ -25	12.0	24.1	116.0	3.3	24.8	4.04	6.07	44.7	2.05
D ₂ -40	11.6	23.9	106.0	3.2	25.0	3.99	5.98	43.2	1.92
LSD _{0.05}	ns ^a	ns	Ns	Ns	ns	ns	ns	ns	0.03
<i>Nutrient levels (kg N-P₂O₅-K₂O/ ha)</i>									
N ₁ -25-0-0	10.0	21.2	99.0	3.1	24.9	3.60	5.70	38.7	1.79
N ₂ -50-50-50	10.7	22.5	110.0	3.3	23.7	3.92	5.89	40.0	1.87
N ₃ -75-50-50	12.4	24.0	112.0	3.9	24.9	4.09	6.14	40.0	1.99
N ₄ -100-50-50	14.1	25.3	124.3	4.7	25.9	4.20	6.30	40.7	2.02
N ₅ -125-50-50	13.9	25.4	122.0	4.3	25.9	4.06	6.10	40.0	1.91
LSD _{0.05}	1.43	1.12	6.43	0.46	ns	0.05	0.07	0.43	0.02
<i>Seedling age</i>									
T ₁ -25days	9.6	24.2	115.0	2.31	27.9	4.09	6.41	39.0	2.04
T ₂ -30days	12.3	24.4	125.0	2.38	28.0	4.28	6.68	39.1	2.10
T ₃ -35days	10.5	23.3	110.5	2.35	26.9	3.97	5.39	42.4	1.92
T ₄ -40days	10.6	22.1	112.8	2.30	27.7	3.73	5.13	42.1	1.78
LSD _{0.05}	1.14	1.40	10.40	0.78	0.27	0.28	0.08	0.32	0.04

^ans, non-significant; ^bBCR, Benefit/Cost Ratio

grain yield, straw yield, and harvest index due to seeding densities.

Maximum number of productive tillers/hill, grains/panicle, panicle weight, 1000-grain weight, straw and grain yield were recorded from the nursery raised with N_4 nutrient management treatment but the difference in these parameters were statistically at par with the N_5 treatment (Table 2). Maximum plant height, 1000-grain weight, grain and straw yields were recorded with 30 days old seedling. Grain yield with 30 days old seedling was recorded 4.64%, 7.8% and 14.74% higher over 25 days, 35 days and 40 days old seedling respectively. Harvest index (HI) with lower seed density was higher than the higher seed density but it was not statistically significant. Comparison of mean values shows that the maximum HI was achieved with the nursery raised with N_4 nutrient management treatment which was 5.16% higher than the nursery raised using N_1 (farmers' practices) nutrient levels (Table 2). Interaction effect between seedling age and nursery nutrient management was significant for grain yield. Thirty days old seedling grown with N_4 nutrient management treatment produced 9.4, 0.22 and 4.6% higher grain yield over 25 days, 35 days and 40 days old seedlings, respectively but there was no significant difference in this parameter due to seedling age. Seedlings grown with treatment N_4 recorded 19.3%, 14.7%, 8.1% and 6.3 % higher grain yields than the treatment N_1 , N_2 , N_3 and N_5 respectively.

Maximum benefit/cost ratio (BCR) of 2.05 was recorded from seedling grown with low seed density (Table 2). About 3.3% additional cost of production with higher seed density was due to additional variable costs. Application of N_5 fertilizer levels in the nursery resulted in highest production costs, whereas, maximum gross return, net return and BCR were recorded with N_4 nutrient management treatment. This was due to increasing variable costs with increasing nutrient doses. Maximum net return and BCR was calculated with 30 days old seedling raised with N_4 nutrient management treatment because of higher grain and straw yields. This may be attributed to the beneficial effects of integrated use of FYM and inorganic fertilizer which continuously provides nutrients required to the nursery. Transplanting of 40 days old seedling had higher production costs than that of 35 and 30 days old seedling, because transplanting of old seedling required more laborers and inputs. There was no significant difference in variable costs between the use of 25 and 30 days old seedling. Highest BCR (2.10) was recorded with 30 days old seedling which was significantly better than the planting of 25, 35 and 40 days old seedling (Table 2). Addition of appropriate rates of FYM has a synergistic effect on improving the efficiency of applied NPK fertilizers and correcting the deficiency of other nutrients, such as Zn and S (Swarup *et al.* 2008). Beneficial effects of higher nutrient application in the nursery along with FYM were also observed by Yaduvanshi and Sharma (2012).

On salt affected soils of the Indo-Gangetic plains, farmers generally use high seed rates, little fertilizers in the nursery, and transplant older seedling which all together

causes low yields. From the present study it is concluded that the transplanting of 30 days old seedling of salt tolerant rice varieties (CSR 36, CSR 43, CSR 46, CSR 56 and CSR 60) raised with seed density of sprouted seed @ 25 g/m² and fertilized with 100-50-50 (25 kg N through 5 t/ha FYM and 75 kg N, full P and K) through chemical fertilizer can produce healthier and vigorous seedling. Healthier seedlings ensure lower mortality and have the capacity to recover faster from the transplanting shock, especially important in sodic soils. Adoption of these improved nursery management practice can be helpful for increasing productivity and profitability of rice in salt affected soils of Indo-Gangetic plains.

ACKNOWLEDGMENTS

The authors express thanks to European Commission-International Fund for Agricultural Development, International Rice Research Institute (IRRI), Philippines, for providing financial support to conduct this study and to the Director, Central Soil Salinity Research Institute, Karnal, Haryana, India, for the support and encouragement.

REFERENCES

- Adhikari B B, Mehera B and Haefele S. 2013. Impact of rice nursery nutrient management, seeding density and seedling age on yield and yield attributes. *American Journal of Plant Sciences* **4**: 146–55.
- Gomez K A and Gomez A A. 1984. *Statistical Procedures for Agricultural Research*, pp 680, 2nd ed. John Wiley and Sons, New York.
- Jackson M L. 1967. *Soil Chemical Analysis*, pp. 183-226. Prentice Hall of India Pvt Ltd., New Delhi, India,
- Kuthe S B. 2012. 'An economic analysis of production and marketing of papaya in tribal taluka of south Gujarat'. M Sc thesis, N AU, Navasari, Gujarat, pp 1–89.
- Mandal A K, Sharma R C and Singh G. 2009. Assessment of salt affected soils in India using GIS. *Geocarto International* **24**(6): 437–56.
- Panigrahy S, Upadhyay G, Ray S S and Parihar J S. 2010. Mapping of cropping system for the Indo-Gangetic plain using multi-date SPOT NDVI-VGT data. *Journal of the Indian Society of Remote Sensing* **38**(4): 627–32.
- Sarwar N, Muhammad M, Wajid S A and Anwar-Ul-Haq, M. 2011. Impact of nursery seeding density, nitrogen, and seedling age on yield and yield attributes of fine rice. *Chilean Journal of Agricultural Research* **71**(3): 343–49.
- Sarangi S K, Maji B, Singh S, Burman D, Mandal S, Sharma D K, Singh U S, Ismail A M and Haefele S M. 2015. Improved nursery management further enhances productivity of stress tolerant rice varieties in coastal rainfed lowlands. *Field Crop Research* **174**: 61–70.
- Singh Y P, Singh R and Gautam A K. 2008. Effect of Nitrogen levels on yield and nutrient uptake by salt tolerant rice and wheat cultivars in gypsum amended alkali soils. *Journal of the Indian Society of Soil Science* **56**(1): 86–91.
- Singh Y P, Mishra V K, Singh S, Sharma D K, Singh D, Singh U S, Singh R K, Haefele, S M and Ismail A M. 2016a. Productivity of sodic soils can be enhanced through the use of salt tolerant rice varieties and proper agronomic practices. *Field Crops Research* **190**: 82–90.
- Singh Y P, Arora S, Mishra V K, Dixit H and Gupta K. 2018.

- Effect of organic and inorganic amendments on amelioration of sodic soil and sustaining rice (*Oryza sativa*) –wheat (*Triticum aestivum*) productivity. *Indian Journal of Agricultural Research* **88**(9): 1455–62.
- Swarup A, Panda D, Mishra B and Kundu D K. 2008. Water and nutrient management for sustainable rice production. (In) *Rice Research Priorities and Strategies for Second Green Revolution, Proceedings of the Research Priorities and Strategies in Rice Production System for Second Green Revolution*. Singh, D P, Dani R C, Rao K S, Rao G J N, Nayak S K, Panda D, Dash R N, Mishra A K and Ghosh A (eds). Central Rice Research Inst., Cuttack, Orissa, pp 79-101.
- Tandon H L S. 1995. *Methods of Analysis of Soils, Plants, Waters and Fertilizers*. FDCO, New Delhi, India.
- Walkley A. 1947. An examination of methods for determining organic carbon and nitrogen in soils. *Agriculture Science* **25**: 598–609.
- Wong V N L, Greene R S B, Dalal R C and Murphy B W. 2010. Soil carbon dynamics in saline and sodic soils: a review. *Soil Use Management* **26**(1): 2–11.
- Yaduvanshi N P S and Sharma D R. 2012. Maximizing of rice yield applied higher loading of fertilizers at nursery stage. Extended summaries. (In) *Third International Agronomy Congress*, New Delhi, p 1241.