**Studies on method of establishment and weed management practices on growth and yield of rice (*Oryza sativa L.*) under irrigated condition**

**ABSTRACT**

A field experiment was conducted during the *Kharif* season of 2018 at the Agronomy Research Farm of Narendra Deva University of Agriculture and Technology (Kumarganj), Ayodhya, Uttar Pradesh to evaluate the impact of different crop establishment methods and weed management practices on the growth and yield of rice. The experiment included three rice establishment methods i.e., transplanting, drum seeding, and direct seeding along with five weed management techniques i.e., Pyrazosulfuron-ethyl 10% WP @ 30 g ha⁻¹ at 5 days after sowing (DAS) or transplanting (DAT), Almix (chlorimuron-ethyl + Metsulfuron-methyl) @ 4 g ha⁻¹ at 10 DAS/DAT, Bispyribac-sodium @ 25 g ha⁻¹ at 30 DAS/DAT, hand weeding at 20 and 40 DAS/DAT, and a weedy check. These treatments were arranged in a factorial randomized block design (FRBD) with three replications, forming fifteen treatment combinations. The findings revealed that the transplanting method of rice establishment significantly enhanced growth parameters such as plant height, number of tillers, leaf area index and dry matter accumulation at all growth stages except at 30 days. It also improved yield attributes, including the number of effective tillers, panicle length, grains per panicle and test weight, leading to higher biological yield (9.71 t ha⁻¹), grain yield (4.78 t ha⁻¹), and straw yield (4.93 t ha⁻¹) compared to the drum-seeded and direct-seeded methods for the NDR-2065 rice variety. Further, among the weed management techniques, two hand weeding at 20 and 40 DAS/DAT resulted in the best growth performance, with increased initial plant population, plant height, number of tillers, leaf area index and dry matter accumulation. This practice also led to improved yield attributes such as the number of effective tillers, grains per panicle, panicle length, test weight, biological yield (10.99 t ha⁻¹), grain yield (5.41 t ha⁻¹), straw yield (5.58 t ha⁻¹) and harvest index (49.25%). The effectiveness of hand weeding was followed by Bispyribac-sodium @ 25 g ha⁻¹ at 30 DAS/DAT, Pyrazosulfuron-ethyl 10% WP @ 30 g ha⁻¹, Almix @ 4 g ha⁻¹, respectively. Thus, the combination of the transplanting method for rice establishment and two hand weeding proved to be the most effective in enhancing growth, yield attributes and overall yield of rice.

**Keyword:** Direct seeding, Drum seeding, Establishment methods, Rice, Transplanting, Weed management

**INTRODUCTION**

More than half of the world's population consumes rice (Oryza sativa L.) as a staple food, and nearly half of Asia's population depends on it for calories. 60% of the world's population is native to Asia, where more than 90% of the world's rice is grown and consumed. Rice will remain the main food source due to the growing population's increased demand for food. Since rice is India's main food crop, the productivity of rice ecosystems plays a major role in the country's food security system (Singh et al., 2020). In India the total area under rice is 47.83 mha and production was 135.76 mt with productivity of 2838 kg ha-1 (Anonymous, 2023).

The primary technique for producing rice in Asia is the manual transplantation of seedlings into puddled soil. Puddling, which involves cultivating soil in standing water, uses a lot of water (Chauhan et al., 2015a), which can occasionally cause the soil's structure to deteriorate and negatively impact the next non-rice crop (Timsina and Connor, 2001). Dry seeding has been shown to be an effective method for growing rice in a number of experiments conducted in China (Yan et al., 2010), South Asia (Malik and Yadav, 2008), and Australia (Beecher et al., 2006). In order to increase or sustain economic output and alleviate issues with soil degradation, direct-seeded rice (DSR) has been created as an alternate way of rice establishment that requires less labor and other inputs (Farooq et al., 2011). An alternative to traditional transplanting that shows promise is drum seeding, especially in regions with water and labor shortages. However, its success depends on effective weed management and proper field preparation (Sudharani et al., 2019)

The variations in weed flora composition in agricultural cropping systems have been thoroughly observed. These changes resulted from selection pressures imposed by modifications and innovations in agricultural technologies, which have altered weed habitats to some extent (Hall et al., 2000). Differences in weed flora also depend on the rice establishment method used. A large number of perennial species [*Paspalum distichum* L., *Cynodon dactylon* (L.) Pers., *Cyperus rotundus* L.] as well as annual grasses (*Ischaemum rugosum* Salisb.) and annual sedges [*Cyperus difformis* L. and *Fimbristylis miliacea* (L.) Vahl] were found in conventional-till DSR systems (Timsina et al., 2010). In the same study, less growth of perennial weeds (*C. dactylon*, *P. distichum*, and *C. rotundus*) and annual weeds (*I. rugosum* and *F. miliacea*) was observed in the zero till DSR system compared with the conventional-till DSR system (Chauhan et al., 2015a). Management of weeds using weed control practices that, on one hand, do not allow weeds to cross the yield losses beyond the economic threshold level and also do not cause any adverse effects on different agro-ecosystems. However, herbicides are considered the most effective and economical weed management tool. Herbicides can be applied as pre-emergence (PRE) or post-emergence (POST), although PRE herbicides are preferred in DSR systems. Different PRE herbicides, including oxadiazon, oxadiargyl, pendimethalin, pyrazosulfuron, pretilachlor, butachlor, and clomazone are now available worldwide and have been reported to provide a fair degree of weed control (Chauhan et al., 2015b). Considering this aspect, the present study was conducted to identify an optimal rice establishment method in combination with an effective weed management practice.

**MATERIAL AND METHODS**

The field experiment was conducted during the *Kharif* season of 2018 at Agronomy Research Farm of Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, which falls under the sub-tropical climate with remarkable humidity and lies between 24.4°North latitudes and 82.10° East longitudes with an altitude of about 113 meter mean sea level. The soil of experimental field was silty loam in texture, basic in reaction (pH 8.1), and electrical conductivity of 0.28 mm hos/cm, low in organic carbon (0.43%), available nitrogen (200.45 kg ha-1), available phosphorous (18.40 kg ha-1), and high in available potassium (295.35 kg ha-1). The experiment consisted of three rice establishment method *viz;* transplanting, drum seeded and direct-seeded method and five weed management technique *viz;* Pyrazosulfuron-ethyl 10% WP @ 30 g ha-1 at 5 days after sowing (DAS)/days after transplanting (DAT), Almix (chlorimuron-ethyl + Metsulfuron-methyl) @ 4 g ha-1 at 10 DAS/DAT, Bispyribac-sodium @ 25 g ha-1 at 30 DAS/DAT, Hand weeding at 20 and 40 DAS/DAT and Weedy check making fifteen treatment combination which was assigned in a Factorial Randomized Block Design (FRBD) and replicated thrice. The paddy variety NDR-2065 was sown on 6th July 2018, transplanted on 30th July 2018 and crop was harvested on 15th November 2018. The recommended dose of fertilizer was 120 kg nitrogen, 60 kg phosphorous, and 60 kg potassium ha-1 and were applied uniformly in each plot. The initial plant population m-2 was recorded at 15 DAS/DAT, plant height, number of tillers m-2, dry matter accumulation, at different growth stages of rice crop. Leaf area index was computed by using the formula as given by yosihida *et al,* (1972). Yield attributing characters like effective tillers, panicle length, number of grains panicle-1,biological yield, straw yield as well as grain yield were recorded at harvest. Harvest index was calculated by using the biological yield (grain + straw) after harvest.

**RESULT AND DISCUSSION**

**Effect of rice establishment method**

The rice establishment method showed significant effect on growth parameters (Table 1), *viz;* plant height, number of tillers m-2, leaf area index, dry matter accumulation. Transplanting method recorded more plant height (79.90 cm), number of tillers (310.77 m-2), leaf area index (4.65), dry matter accumulation (950.33 g m-2) over direct seeding method but being at par with drum seeding method. While initial plant population were not affected significantly due to different establishment methods. Numerically the maximum plant population (52.60 m-2) was found under transplanting method and lowest (52.04 m-2) was recorded under direct seeded method. The plant population remained statistically unaffected due to uniform seed rate across methods, the transplanting method's superiority in plant height, tiller number, leaf area index, and dry matter accumulation is attributed to better seedling establishment, reduced early weed competition, and efficient nutrient uptake. The present result are in agreement with those of Naresh *et al.* (2013), Raj *et al.* (2013), Yadava *et al.* (2014) and Netam *et al.* (2018).

**Table 1: Effect of establishment methods and weed management practices on growth attributes of rice crop.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Treatment** | **Initial plant population**  **(m-2)** | **Plant height (cm)** | **Number of tillers (m-2)** | **Leaf area index** | **Dry matter accumulation**  **(g m-2)** |
| **Method of rice establishment** | | | | | |
| Transplanting | 52.60 | 79.90 | 310.77 | 4.65 | 950.33 |
| Drum seeded | 52.26 | 76.33 | 295.18 | 4.41 | 903.34 |
| Direct seeded | 52.04 | 72.47 | 279.59 | 4.22 | 858.13 |
| SEm± | 0.95 | 1.38 | 5.38 | 0.08 | 16.42 |
| LSD (P=0.05) | NS | 4.03 | 15.65 | 0.23 | 47.82 |
| **Weed management technique** | | | | | |
| Pyrazosulfuron-ethyl 10% WP @ 30 g ha-1 | 52.35 | 75.01 | 298.47 | 4.33 | 954.34 |
| Almix @ 4 g ha-1 | 51.39 | 73.82 | 293.62 | 4.29 | 935.15 |
| Bispyribac sodium @ 25 g ha-1 | 52.98 | 80.93 | 319.65 | 4.65 | 1037.33 |
| Hand weeding | 53.67 | 86.47 | 343.90 | 4.99 | 1112.77 |
| Weedy check | 51.11 | 64.94 | 220.27 | 3.86 | 480.06 |
| SEm± | 1.23 | 1.79 | 6.94 | 0.10 | 21.20 |
| LSD (P=0.05) | NS | 5.20 | 20.21 | 0.30 | 61.73 |

Different crop establishment method exhibited significant influence on all the yield attributes studied (Table 2). Among them, transplanting method produced higher yield attributes *viz;* number of effective tillers (294.09 m-2), length of panicles (22.92 cm), number of grains per panicle (100.01) over direct seeded method, however it was at par with the drum seeded method. This might be due to better seedling vigor, less intra-plant competition, and effective resource use are the reasons for the transplanting method's greater production qualities. The result are in agreement with the finding of Naresh *et al.* (2013), Raj *et al.* (2013), Rana *et al.* (2014) and Tao *et al.* (2016).While test weight was not influence significantly due to establishment method but numerically maximum value (22.57 g) was recorded under transplanting and as a minimum (22.02 g) was found under direct seeding method. Test weight was unaffected because it is mostly determined by genetic variables rather than establishment techniques. Similar finding were reported by Awan *et al.* (2007), Saharawat *et al.* (2010).

Grain and straw yield is direct result of growth and yield attributes of the crop. The various rice establishment method showed significant impact on rice yield (Table 3) *viz;* biological yield, grain yield, and straw yield. The transplanting method being recorded higher biological yield (9.71 t ha-1), grain yield (4.78 t ha-1), and straw yield (4.93 t ha-1) over direct seeded rice. While drum seeding method of rice establishment being recorded at par with both of the treatment. The percentage increment over drum seeding of 7.43%, 4.87% and direct seeding of 13.27%, 10% in grain and straw yield, respectively during the year of investigation. Although harvest index was not significantly influenced by various method of establishment but numerically highest value (49.10 %) was found under transplanting and lowest value (48.04 %) was found under direct seeding method. The transplanting method's increased grain, straw, and biological yields are ascribed to improved growth and yield features brought about by improved crop establishment, increased tillering capacity, and effective nutrient uptake. Direct seeding produced lower yields because of increased early weed competition and less-than-ideal root development, whereas drum seeding performed similarly to transplanting in terms of plant stand and resource usage. The result were in co-ordination with earlier finding of Sridevi *et al.* (2017), Singh *et al.* (2017) and Kumar *et al.* (2018).

**Effect of weed management technique**

Growth attributes like plant height, number of tillers m-2, leaf area index and dry matter accumulation are the reflective process of effective utilization of resources in a better crop production environment. Dramatic variation in growth parameters of rice was noticed due to different weed control methods (Table 1). The highest plant height (86.47 cm), number of tillers (343.90 m-2), leaf area index (4.99) and dry matter accumulation (1112.77 g m-2) was recorded by hand weeding twice which was significantly superior followed by bispyribac-sodium @ 25 g ha-1 at 30 DAS/DAT over rest of the treatment. However weedy check treatment recorded significantly lower plant height (64.94 cm), number of tillers (220.27 m-2), leaf area index (3.86) and dry matter accumulation (480.06 g m-2) over rest of the weed management technique. The initial plant population was not influenced significantly due to various weed management techniques but numerically highest was recorded under manual weeding twice at 20 and 40 DAS/DAT (53.67) followed by bispyribac-sodium @ 25 g ha-1 at 30 DAS/DAT (52.98) and lowest was observed under weedy check (51.11). Effective weed management lowers competition for vital resources like nutrients, water, and sunlight, increasing plant vigor and biomass accumulation. This is why the maximum growth parameters were seen during the two hand weeding sessions. Due to intense competition from weeds, crop development was inhibited and resource availability was restricted, resulting in noticeably lower values in the weedy check. The results are consistent with those of Kumar et al. (2018).

**Table 2: Effect of establishment methods and weed management practices on yield attributes of rice crop.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatments** | **Effective Tiller**  **(No. m-2)** | **Length of panicles (cm)** | **No. of grain panicle-1** | **Test weight (g)** |
| **Methods of rice establishment** | | | | |
| Transplanting | 294.09 | 22.92 | 100.01 | 22.57 |
| Drum seeded | 280.10 | 21.80 | 96.03 | 22.20 |
| Direct seeded | 267.29 | 20.67 | 91.10 | 22.02 |
| SEm ± | 5.11 | 0.39 | 1.75 | 0.40 |
| LSD (P=0.05) | 14.87 | 1.15 | 5.10 | NS |
| **Weed management techniques** | | | | |
| Pyrazosulfuron-ethyl 10% WP @ 30 g ha-1 | 283.79 | 21.42 | 94.04 | 22.34 |
| Almix @ 4 g ha-1 | 279.14 | 20.59 | 92.40 | 21.38 |
| Bispyribac sodium @ 25 g ha-1 | 304.50 | 23.41 | 103.49 | 22.96 |
| Hand weeding | 329.85 | 25.01 | 112.44 | 23.57 |
| Weedy check | 205.18 | 18.54 | 76.19 | 21.07 |
| SEm ± | 6.59 | 0.51 | 2.26 | 0.52 |
| LSD (P=0.05) | 19.20 | 1.48 | 6.58 | 1.52 |

The yield attributes *viz;* effective tillers, number of grain per panicles and length of panicles was influenced significantly with different weed management technique (Table 2). Among various weed management technique, hand weeding twice being recorded significantly higher value of these yield attributes followed by bispyribac-sodium @ 25 g ha-1 at 30 DAS/DAT over Pyrazosulfuron-ethyl 10% WP @ 30 g ha-1, Almix (chlorimuron-ethyl + Metsulfuron-methyl) @ 4 g ha-1 and thereafter weedy check. While the test weight was not influenced significantly due to various weed management techniques but numerically highest test weight (23.57 g) was recorded under hand weeding at 20 and 40 DAS/DAT followed by bispyribac-sodium @ 25 g ha-1 at 30 DAS/DAT (22.96 g) and lower test weight (21.07 g) was recorded under weedy check. Due to efficient weed removal, which reduced competition for nutrients, water, and light, hand weeding twice improved tiller production, panicle length, and grain formation, all of which led to greater yield qualities. Since test weight is mostly determined by the rice variety's genetic potential rather than weed control techniques, it remained statistically unaltered. The finding is in conformity with the result of Kumar *et al.* (2018).

The biological, grain and straw yield varied significantly with various weed management techniques. Manual weeding twice at 20 and 40 DAS/DAT achieved significantly higher biological yield (10.99 t ha-1), grain yield (5.41 t ha-1) and straw yield (5.58 t ha-1) followed by bispyribac-sodium @ 25 g ha-1 at 30 DAS/DAT as post emergence alone over rest of weed management techniques. The percentage increment of hand weeding over Pyrazosulfuron-ethyl was 14.26%, 12.89%, Almix was 17.72%, 16.62%, bispyribac-sodium was 6.19%, 7% and weedy check of 111.15%, 85.68% in grain and straw yield, respectively. The percentage increment of bispyribac-sodium over Pyrazosulfuron-ethyl was 7.59%, 5.50%, Almix was 10.85%, 8.99%, and weedy check was 98.82%, 73.53% in grain and straw yield, respectively. The lowest biological yield (5.57 t ha-1), grain yield (2.57 t ha-1) and straw yield (3.00 t ha-1) was recorded by weedy check. While harvesting index was not significantly influenced by various weed management technique but numerically highest value (49.43 %) was given by bispyribac-sodium @ 25 g ha-1 at 30 DAS/DAT and lowest value (45.79 %) was found under direct seeding method. Due to efficient weed removal that reduces competition for nutrients, water and light, the superior yields achieved with hand weeding twice at 20 and 40 DAS/DAT improve crop growth and yield characteristics. High yields were also demonstrated with bispyribac-sodium @ 25 g ha⁻¹ at 30 DAS/DAT, which successfully suppressed weeds during the crucial growth periods and lessened their negative effects. Due to intense weed competition, which inhibited crop development, decreased nutrient availability, and impeded biomass buildup, the weedy check had the lowest yield.

Similar result were obtained by Baloch *et al.* (2006) and sairam *et al*. (2012).

**Table 3: Effect of establishment methods and weed management practices on yield of rice crop**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatments** | **Grain yield**  **(t ha-1)** | **Biological yield**  **(t ha-1)** | **Straw yield**  **(t ha-1)** | **Harvest index**  **(%)** |
| **Methods of rice establishment** | | | | |
| Transplanting | 4.78 | 9.71 | 4.93 | 49.10 |
| Drum seeded | 4.45 | 9.15 | 4.70 | 48.32 |
| Direct seeded | 4.22 | 8.70 | 4.48 | 48.04 |
| SEm± | 0.08 | 0.17 | 0.09 | 0.88 |
| LSD (P=0.05) | 0.24 | 0.48 | 0.25 | NS |
| **Weed management techniques** | | | | |
| Pyrazosulfuron-ethyl 10% WP @ 30 g ha-1 | 4.74 | 9.68 | 4.94 | 48.95 |
| Almix @ 4 g ha-1 | 4.60 | 9.38 | 4.78 | 49.02 |
| Bispyribac sodium @ 25 g ha-1 | 5.10 | 10.31 | 5.21 | 49.43 |
| Two hand weeding | 5.41 | 10.99 | 5.58 | 49.25 |
| Weedy check | 2.57 | 5.57 | 3.00 | 45.79 |
| SEm± | 0.10 | 0.21 | 0.11 | 1.14 |
| LSD (P=0.05) | 0.30 | 0.62 | 0.32 | NS |

**CONCLUSION**

From the one year experimentation conclusion can be drawn that thetransplanting method of rice establishment along with two hand weeding at 20 and 40 DAS/DAT was most effective in promoting growth and yield of rice crop compared to any other method of crop establishment and weed management.

**COMPETING INTERESTS DISCLAIMER:**

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

**REFERENCES:**

Anonymous, (2023). Area, production and yield of India & state. In: Agricultural Statistics at a Glance. Government of India Ministry of Agriculture & Farmers Welfare, Department of Agriculture, Cooperation & Farmers Welfare, Directorate of Economics and Statistics, 87–89.

Awan, T.H., Ali, I., Safdar, M.E., Ashraf, M.M. and Yaqub, M. (2007). Economic effect of different plant establishment techniques on rice production. *Journal of Agricultural Research,* **45**(1): 73-80.

Baloch, Md. S., Awan, I. U., Hassan, Gul and Khakwani, Abdul Aziz (2006). Effect of Establishment Methods and Weed Management Practices on Some Growth Attributes of Rice. *Rice Science* **13** (2): 131-140.

Beecher, G., Dunn, B., Mathews, S., Thompson, J., Singh, R.P., Humphreys, L., Timsina, J., O’Keefe, K. and Johnston, D. (2006). Permanent beds for sustainable cropping. IREC Farmers’ Newsletter No. 171. Summer 2006.

Chauhan, B.S., Awan, T.H., Abugho, S.B., Evengelista, G. and Yadav, S. (2015a). Effect of crop establishment methods and weed control treatments on weed management, and rice yield.  *Field Crop Research,* 172: 72-84. <http://dx.doi.org/10.1016/j.fcr.2014.12.011>

Chauhan, B.S., Ahmed, S., Awan, T.H., Jabran, K. and Manalil, S. (2015b). Integrated weed management approach to improve weed control efficiencies for sustainable rice production in dry-seeded systems.  *Crop Protection.*  71: 19-24. <https://doi.org/10.1016/j.cropro.2015.01.012>

Farooq, M., Siddique, K.H.M., Rehman, H., Aziz, T., Lee, D.J. and Wahid, A. (2011). Rice direct seeding: experiences, challenges and opportunities. Soil Till. Res. 116, 260–267.

Hall, J.C., Van Eerd, L.L., Miller, S.D., Owen, M.D.K., Prather, T.S., Shaner, D.L., Singh, M., Vaughn, K.C. and Weller, S.C. (2000). Future research directions for weed science. Weed Technol. 14, 647–658.

Kumar, Sanjay, Pandey, Nareshmani, Kumar, Ajit, Singh, A. K., Gopal, Tarun and Kumar,Dinesh (2018).Effect of Establishment Methods and Weed Management Practices on Economics of Direct Seeded Rice (*Oryza sativa* L.).*International Journal of Current Microbiology and Applied Sciences* **7** (04): 1473-1480.

Malik, R.K. and Yadav, A. (2008). Direct-seeded rice in the Indo-Gangetic Plain: progress, problems and opportunities. In: Humphreys, E., Roth, C.H., (Eds.), Proceedings of permanent beds and rice residue management for rice–wheat systems in the Indo-Gangetic Plains. ACIAR Workshop Proceedings No. 127, ACIAR. Canberra, Australia, pp. 124–132.

Naresh, R.K., Misra, A.K. and Singh, S.P. (2013). Assessment of direct seeded and transplanting methods of rice cultivars in the western part of Uttar Pradesh. *International Journal of Pharmaceutical Sciences and Business Management,* **1**(1):1-8.

Netam, C.R., Netam, R., Qureshi, A., Banjare, K. and Netam, A.K. (2018). Influence of various weed management approaches on weed dynamics in rice under different crop establishment methods. *International Journal of Current Microbiology and Applied Sciences,* **7**(3): 1551-1557.

Raj, S.K., Jose, N., Mathew, R. and Leenakumary, S. (2013). Influence of stand establishment techniques on yield and economics of rice cultivation of Kuttanand. *International Journal of Scientific and Research Publications,* **3**(4):1-6.

Rana, M.M., Mamun, M.A.A., Zahan, A., Ahmed, M.N. and Mridha, M.A.J. (2014). Effect of planning methods on the yield and yield attributes of short duration *Aman* rice. *American Journal of Plant Sciences,* **5**:251-255.

Saharawat, Y.S., Singh, B., Malik, R.K., Ladha, J.K., Gathala, M., Jat, M.L. and Kumar, V. (2010). Evaluation of alternative tillage and crop establishment methods in a rice-wheat rotation in North Western IGP. *Field Crops Research,* **116**:260-267.

Sairam, C. V., Hanji, M. B., Prabhukumar, S. and Nand Kishor, (2012). Crop-weed competition and weed management studies in direct seeded rice (*Oryze sativa*). *Indian Journal of Agronomy;* **57**(1):38-42.

Singh, D.K., Pandey, P.C., Thapliyal, S.D. and Nanda, G. (2017). Yield and economics of rice as influenced by establishment methods and varieties under mollisols of Pantnagar. *International Journal of Current Microbiology and Applied Sciences,* **6**(6):297-306.

Sridevi, V., Jeyaraman, S., Ramasamy, S. and Chinnusamy, C. (2017). Influence of crop establishment methods, weed and nutrient management practices on growth and yield of direct seeded rice. *International Journal of Current Microbiology and Applied Science,* **6**(11): 3725-3737.

Sudharani, J.S., Aruna, K. and Ramakrishna Babu, A. 2019. Drum Seeder a Promising Low Cost Technology in Rice Production System for Small and Marginal Farmers of Mahabubnagar District, India. *Int.J.Curr.Microbiol.App.Sci.* 8(02): 784-788. <https://doi.org/10.20546/ijcmas.2019.802.090>

Tao, Y., Chen, Q., Peng, S., Wang, S. and Nie, L. (2016). Lower global warming potential and higher yield of wet direct-seeded rice in Central China. *Agronomy of Sustainable Development,* **36**:1-9.

Timsina, J. and Connor, D.J. (2001). The productivity and sustainability of the rice–wheat cropping systems: issues and challenges. Field Crops Res. 69, 93–132.

Yadav, S., Evangelista, G., Faronilo, J., Humphreys, E., Henry, A. and Fernandez, L. (2014). Establishment method effects on crop performance and water productivity of irrigated rice in the tropics. *Field Crops Research,* **166**: 112-127.

Yan, J., Yu, J., Tao, G.C., Vos, J., Bouman, B.A.M., Xie, G.H. and Meinke, H. (2010). Yield formation and tillering dynamics of direct-seeded rice in flooded and nonflooded soils in the Huai River Basin of China. Field Crops Res. 116, 252–259.

Yoshida S., Cock J.H. and Parao F.T. (1972). Physiological aspects of high yield. *Int. Rice Res. Inst. Rice breeding*, pp. 455-469.