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Weed Dynamics in Rice (*Oryza sativa* L.) as Influenced by Different Establishment Methods and Nutrient Management Practices

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ABSTRACT: Weed flora in rice is affected by establishment methods and nutrient management practices. Effective weed management is the key to get higher rice yield which needs thorough investigation of weed flora. Therefore, a field experiment was conducted at Pantnagar, Uttarakhand during *Kharif*, 2018 and 2019 to study the effect of different establishment methods and nutrient management practices on weed dynamics of rice (*Oryza sativa* L.). Four establishment methods (transplanting, system of rice intensification, direct seeded rice and wet-direct seeded rice) and five nutrient management practices (100 % RDF, 75 % RDF + FYM (equiv. to 25 % N), 150 % RDF, RDF (LCC based N application) and RDF + 5 t FYM) were tested in split plot design with three replication using rice variety PR-121 as test crop. An area of 5 m^2 out of 20 m^2 was earmarked in each plot for studying weed dynamics and weed dry matter as influenced by different establishment methods and nutrient management practices. Results showed that different establishment methods and nutrient management practices significantly affected the weed dynamics in rice. The highest species wise weed density was found under direct seeded rice as compared to other establishment methods followed by wet direct seeded rice and the minimum species wise weed density was found under system of rice intensification during both the year of experimentation. The highest total weed density and dry weight was observed under direct seeded rice as compared to other establishment methods during both the year of experimentation. Nutrient management practices had non-significant effect on species wise weed density during both the year of study. The maximum total weed density and dry weight was observed under RDF + 5 t FYM during both the year of study except total weed density during 2018 where the nutrient management practices had non-significant effect.

Key words: Rice, Establishment methods, Nutrient management practices, weed dry matter and weed density.

INTRODUCTION

Rice (*Oryza sativa* L.) is the world's most significant staple food crop sustaining more than half of the world's population on daily basis. Rice is the most important and widely produced food grain crop in India covering an area of 43.79 million hectares with a total production of 112.91 million tons (Anonymous, 2018). However, India's productivity (2.4 t ha^{-1}) is lower than global average yields (4.4 t ha^{-1}) and well behind Egypt's, Japan's and China's rice production (Shendage *et al*., 2019). There are a number of factors which are responsible for lower productivity of rice such as establishment method, nutrient management and weeds. In India, rice is mainly cultivated by two methods either by transplanting or sowing directly. Primarily rice is grown via transplanting method in *Tarai* region of Uttarakhand, which has numerous drawbacks, including more labor requirement, a lot of expense on nursery, uprooting and transplanting and detrimental influence on soil and environmental health **(**Nazir *et al.,* 2020**;** Awan *et al.,* 2007). Besides this, rice cultivation with traditional transplanting needs a large amount of irrigation water, ranging between 1,500 and 3,000 mm. We know that there will be a water crisis in the near future due to diminishing water supplies and rising demand from other competing consumers of water, such as household and industrial usage (Singh *et al.*, 2017). Under such circumstances, we need more efficient alternative rice producing methods to maintain the long-term rice production as well as productivity. In India, several farmers are altering their rice establishment methods from transplanting to direct seeding in puddled soil (Wet-DSR) and dry direct seeding in unpuddled soil (Dry-DSR) due to the current water and labor shortages. DSR presents a significant opportunity to alter production techniques in water-scarce locations in order to achieve optimal plant density, yield and water productivity. The adoption of DSR method for lowland rice culture would significantly decrease costs of rice production. Further, direct dry seeded rice (DSR), which eliminates the puddling and drudgery of transplanting immature rice seedlings offers a solution to the edaphic conflict and improves the sustainability of the rice-wheat cropping system (Bhaskar *et al*., 2018). System of rice intensification is a technique of transferring rice production that entails changing the genetic potential of rice in order to produce a favorable growing environment that boosts the productivity and profitability. In addition, it improves soil health and income of farmers by reducing the consumption of inputs such as seeds and water (Kirar *et al*., 2018 and Bhagwati *et al*., 2020).

Good nutrient management practice could boost rice production. The relative availability of nutrients from organic and inorganic sources for absorption by crop differs. Chemical fertilizers are a rapid source of nutrient delivery and are readily available to crop as most of fertilizers are water soluble (Kumar *et al*., 2014). On the other hand, organic manure is a nearly complete source of most nutrients and due to its low nutrient content and bulky nature; it becomes gradually available for crop uptake depending upon the nature of decomposition. The gradual release of nutrients enriches the labile pool for a longer period of time which provides the nutrients during crop growing period (Puli *et al.,* 2017). Thus, we need an integrated approach involving the use of organic and inorganic fertilizers to ensure that crops receive all of the important nutrients in appropriate levels and that the nutrients are easily available during crop growth (Singh *et al*., 2019).

Weed infestation is a key challenge for increasing rice yield (Nazir *et al*., 2020). Weed flora in rice crop changes with the change in rice establishment method from conventional manual transplanting of seedlings to dry direct seeding, wet direct seeding and system of rice intensification methods. Crop and weed competition is more in direct-seeded rice as compared to transplanted rice, because the land is exposed till the initial seedling establishment in direct seeded rice (Shendage *et al*., 2019). Weed flora has a more competitive interaction with applied plant nutrients than crop flora because weeds absorb nutrients faster and more efficiently than crop plants. Weed communities can be influenced by nutrient management methods in two ways: directly through seed immigration and indirectly through changes in competitive capacities. Weed seeds can move to agricultural fields via manure, increasing the weed seedbank density and species diversity. Therefore, plant nutrition management may play an important role in regulating weed interference in crops. With manure treatments, new difficult-to-control weeds might be introduced in some situations (Cordeau *et al*., 2021). Thus, we need an appropriate nutrient management practice which overcomes the crisis of weed infestation. Limited literature is available on effect of establishment method and nutrient management practices in rice on weed dynamics in Tarai region of Uttarakhand. However, how these two factors interact with respect to weed dynamics in this region is not available. Keeping these above facts in mind, the present study was undertaken.

MATERIALS AND METHODS

A field experiment was conducted during *Kharif* season of 2018 and 2019 in the Rice Agronomy A_2 Block at the N. E. Borlaug Crop Research Centre, G. B. Pant university of Agriculture and Technology, Pantnagar, Uttarakhand. The soil was silty loam in texture with pH 7.6, having 0.87% organic carbon, 227.31 kg/ha available N, 19.6 kg/ha available P and 202 kg/ha available K. The experiment was laid out in split plot design having three replications with four different establishment methods (M_1- transplanted rice (TPR), M_2- system of rice intensification (SRI), M_3- direct seeded rice (DSR) and M_4- wet-direct seeded rice (WDSR)) alloted to main plots and five nutrient management practices (F_1- 120:60:40 NPK (100 % RDF), F_2- 75 % inorganic + FYM (equiv. to 25 % N), F_3- 180:90:60 NPK (150 % RDF), F_4 - LCC based nitrogen application (having 3 shade as crucial for N application of 30 kg ha^{-1}) and F_5- 100 % RDF + 5 tonns FYM (Farmer's practice) in sub-plots. The rice variety 'PR-121' was seeded using seed rates of 30 and 6 kg ha^{-1} in nurseries for manual transplanting (M_1) and system of rice intensification method (M_2), respectively. In well puddled transplanted rice plots, 21-days old seedlings were manually transplanted at 20 cm × 20 cm spacing. In, systems of rice intensification, 11-day-old seedlings were transplanted at 25 cm × 25 cm spacing. In direct seeded rice, seed was manually sown in lines 20 cm apart at a seed rate of 40 kg ha^{-1}. Water soaked pre-sprouted seeds were disseminated at a rate of 40 kg ha^{-1} in well prepared rice plots in the wet direct seeded rice. A uniform pre-sowing irrigation was applied to all plots for seed bed preparation and water was applied as per need to maintain optimum soil condition. The fertilizer was applied as per the treatment, a full dose of phosphorus and potassium, as well as 50 % nitrogen, was applied as basal in all rice-established plots using urea (46 % N), NPK fertilizer (12:32:16) and murate of potash (60 % K_2O. The remaining nitrogen was applied in two split doses, one at tillering (50% in direct seeded and wet direct seeded plots and 25% in transplanted rice plots) and the other at panicle initiation (25% N was applied in all plots as per the treatment). Prior to sowing or transplanting, FYM was applied as per treatment on required sub-plots and thoroughly incorporated into the top 15 cm soil with the help of a spade manually.

An area of 5 m^2 out of 20 m^2 was earmarked in each plot for studying weed dynamics and weed dry matter as influenced by different establishment methods and nutrient management practices. Weed density and dry matter were recorded at 60 days after sowing/transplanting (DAS/DAT) with the help of a quadrate (0.5 m × 0.5 m) and then converted to per square meter. Data on weeds were subjected to square root transformation before statistical analysis to normalize their distribution. All the data were analyzed using analysis of variance for split plot design (Gomez and Gomez, 1984) and the critical difference (CD) value at 5% level of significance was calculated and used to test significant differences between treatment means.

RESULTS AND DISCUSSION

Crop yield loss differs depending on the types of weed infestation during the crop growth cycle, as well as their density. The competitive ability of weed species varies based on their morphology and physiology. Therefore, detailed observations of weeds associated with rice crop were studied during experimentation.

Weed flora. Five major weed species with percent contribution at 60 DAS/DAT are presented in Table-1. The major weed flora found in the experimental fields during 2018 and 2019 were *Echinochloa colona, Leptochloa chinensis*, *Echinochloa crusgalli*, *Cyperus rotundus, Caesulia axillaris* and other weeds.

Establishment methods: In transplanting method, *Caesulia axillaris* (21.3 and 21.5 %) species had the highest dominance closely followed by *Cyperus rotundus* (21.1 and 21.0 %) and *Echinochloa crusgalli* (12.9 and 11.5 %) had the lowest dominance during both the years. In system of rice intensification, *Caesulia axillaris* (21.4 %) species had the highest dominance during the year 2018 while in 2019 *Leptochloa chinensis* (20.4 %) had the highest dominance compared to other species. In direct seeded rice, *Caesulia axillaris* (21.0 and 20.9 %) species showed the highest density as compared to other weed species during both the years closely followed by *Leptochloa chinensis* (17.8 and 18.5 %) and *Cyperus rotundus* (18.2 and 17.8 %) species during both the years of experimentation. In wet direct seeded method, *Caesulia axillaris* (20.2 %) in the year 2018 and *Leptochloa chinensis* (19.4 %) in the year 2019 showed the highest dominance compared to other species closely followed by *Cyperus rotundus* (18.3 and 18.4 %) during both the years. *Echinochloa colona* (12.6 %) species in 2019 and *Echinochloa crusgalli* (12.4%) species in 2018 had the lowest dominance.

Nutrient management practices: The various nutrient management practices had different types of weed flora in experimental field during both the year of study. In nutrient management practice 100 % RDF, 75 % RDF + FYM (equiv. to 25 % N) and 150 % RDF, *Caesulia axillaris* shared 21.5, 19.0 and 17.9 %, respectively of the total weeds in 2018 whereas *Leptochloa chinensis* shared 20.1, 19.7 and 20.1 %, respectively of the total weeds in 2019. *Echinochloa crusgalli* sharing 12.3, 12.7 and 12.3 %, respectively in the above nutrient management practices in 2018 and *Echinochloa colona* sharing 13.1, 14.3 and 13.9 %, respectively in the above nutrient management practices during the year 2019 recorded the lowest dominance. In nutrient management practice RDF (LCC based N), *Caesulia axillaris* showed the highest dominance (20.6 and 20.3 %) closely followed by *Cyperus rotundus* (18.6 %) during both the year of study. *Echinochloa crusgalli* (14.0 %) and *Echinochloa colona* (15.2 %) in 2018 and 2019, respectively showed the lowest dominance compared to other species. In nutrient management practice RDF + 5 t FYM, *Caesulia axillaris* (21.4 and 19.9 %) had the highest dominance as compared to other species followed by *Cyperus rotundus* (18.7 and 18.8 %) during both the years of study and *Echinochloa crusgalli* (12.3 and 13.0 %) showed lesser dominance as compared other species during both the year of study.

Table 1: Effect of establishment method and nutrient management practices on major weed species (per cent of total weeds) at 60 DAS/DAT of rice.

TREATMENTS	*E. colona*		*L. chinensis*		*E. crusgalli*		*C. rotundus*		*C. axillaris*		Other weeds	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Establishment Methods (M)												
TPR	15.7	13.7	12.9	17.9	12.9	11.5	21.1	21.0	21.3	21.5	16.2	14.5
SRI	17.9	16.2	13.7	20.4	13.6	14.0	16.4	16.3	21.4	17.7	17.0	15.4
DSR	16.2	14.2	17.8	18.5	12.0	14.2	18.2	17.8	21.0	20.9	14.8	14.5
WDSR	16.8	12.6	17.5	19.4	12.4	18.1	18.3	18.4	20.2	18.1	14.8	13.4
Nutrient Management Practices (F)												
100 % RDF	17.2	13.1	15.7	20.1	12.3	15.9	17.4	17.5	21.5	18.5	15.9	14.8
75 % RDF + FYM (equiv. to 25 % N)	16.9	14.3	15.8	19.7	12.7	13.8	19.3	19.0	20.7	19.5	14.6	13.7
150% RDF	16.7	13.9	16.1	20.1	12.3	14.2	18.5	17.9	20.5	19.5	15.8	14.4
RDF(LCC based N)	16.1	15.2	14.6	17.0	14.0	15.4	18.6	18.6	20.6	20.3	16.1	13.6
RDF+ 5 t FYM	16.4	14.4	15.1	18.3	12.3	13.0	18.7	18.8	21.4	19.9	16.1	15.7

Species wise weed density

Establishment method: Data presented in Table-2 and 3 showed that different establishment methods significantly influenced the species wise weed density (no. m^{-2}) during both the year of study. The species wise density of weeds followed the order: *Caesulia axillaris* >*Cyprus rotundes* > *Leptochloa Chinensis* > *Echinochloa colona* > *Echinochloa crusgalli* under all the establishment methods and nutrient management practice during both the year of study. Among the establishment methods, the lowest species wise density of weed was recorded under system of rice intensification followed by transplanting during both the year of study. The highest species wise density of weed was found under direct seeded rice method followed by wet-direct seeded rice method during both the year of study. The highest weed density was recorded in direct seeded rice method over other establishment methods because unpuddled condition in direct seeded rice is congenial for weed seed germination and its survival. Further, higher weed density in direct sown rice was mainly attributed to early weed germination than the crop germination. System of rice intensification resulted in lower weed density due to puddling which buries the weeds into the lower layers of the mud, where they can be decomposed by anaerobic action resulting in lesser emergence of deeply placed weed seeds. These results are in conformity with the findings of Singh *et al*., (2005); Subramanian *et al*., (2007); Bhat *et al*., (2011) and Saha and Bharti, (2010).

Nutrient Management: A critical examination of data presented in Table 2 and 3 indicated that different nutrient management practices could not cause significant variation on species wise density of weed during both the year expcept *Echinochloa colona* and *Cyperus rotundus* during 2019. The nutrient management practice RDF + 5 t FYM recorded the highest weed density followed by 100 % RDF but found at par with nutrient management practices 75 % RDF + FYM (equiv. to 25 % N), 150 % RDF and RDF (LCC based N) in the year 2019. This is because weed seeds can immigrate to crop fields through manure application and increase the weed seed bank density and species diversity (Cordeau *et al*., 2021).

Table 2: Effect of different establishment methods and nutrient management practices on weed density (no. m^{-2}) at 60 DAS/DAT stage of rice.

Treatments	*Echinochloa colona*		*Leptochloa Chinensis*		*Echinochloa crusgalli*	
	2018	2019	2018	2019	2018	2019
Establishment Methods (M)						
TPR	3.39 (14.51)	3.33 (10.64)	3.52 (11.94)	3.77 (13.94)	3.51 (11.88)	3.05 (8.88)
SRI	2.54 (8.40)	2.62 (6.40)	2.62 (6.39)	2.90 (8.06)	2.61 (6.35)	2.44 (5.55)
DSR	4.28 (22.63)	4.27 (17.83)	5.02 (24.79)	4.78 (23.29)	4.14 (16.82)	4.26 (17.82)
WDSR	3.89 (18.97)	3.71 (14.09)	4.48 (19.70)	4.65 (21.16)	3.71 (14.08)	4.51 (19.95)
SEm±	0.08	0.09	0.06	0.08	0.10	0.06
CD(*P*=0.05)	0.29	0.31	0.19	0.26	0.34	0.20
Nutrient Management Practices (F)						
100 % RDF	3.51 (16.61)	3.14 (10.11)	3.93 (15.95)	4.02 (16.29)	3.35 (11.83)	3.67 (14.08)
75 % RDF + FYM (equiv. to 25 % N)	3.42 (16.00)	3.47 (12.00)	3.91 (15.59)	4.04 (16.59)	3.47 (11.94)	3.46 (12.27)
150% RDF	3.51 (16.27)	3.50 (12.18)	4.01 (16.58)	4.07 (17.98)	3.46 (11.85)	3.53 (12.68)
RDF(LCC based N)	3.56 (15.27)	3.64 (13.26)	3.80 (14.77)	3.90 (15.36)	3.67 (13.35)	3.67 (13.60)
RDF+ 5 t FYM	3.62 (16.78)	3.67 (13.64)	3.92 (15.63)	4.07 (16.83)	3.52 (12.45)	3.49 (12.62)
SEm±	0.06	0.09	0.07	0.09	0.08	0.07
CD(*P*=0.05)	NS	0.26	NS	NS	NS	NS
M × F	NS	S	NS	NS	S	S

Interaction effect: Interaction effect: For the density of *Echinochloa crusgalli* during the years 2018 and 2019 and *Echinochloa colona* species during the year 2019 at 60 DAS/DAT different establishment methods and nutrient management practices interacted significantly. During the year 2018 the highest density of *Echinochloa crusgalli* species was found in direct seeded method under 100 % RDF nutrient management practice over other nutrient management practices and establishment methods while the lowest was found in wet-direct seeded method under nutrient management practice 100 % RDF as compared to remaining combinations. In transplanted and system of rice intensification method, nutrient management practices RDF (LCC based N) gave the highest weed density of *Echinochloa crusgalli* but found at par with other nutrient management practices except for RDF + 5 t FYM during 2018. In wet-direct seeded method, nutrient management practice RDF (LCC based N) gave the highest weed density of *Echinochloa crusgalli* species over other nutrient management practices but found at par with RDF + 5 t FYM practices (Table 2a).

Table 2a: Interaction effect of different establishment methods and nutrient management practices on weed density of *Echinochloa crusgalli* at 60 DAS/DAT during 2018.

Nutrient management practices (F)	Establishment methods (M)			
	TPR	**SRI**	**DSR**	**WDSR**
100 % RDF	3.65	2.69	4.82	2.25
75 % RDF + FYM (equiv. to 25 % N)	3.52	2.58	4.17	3.60
150% RDF	3.52	2.53	3.86	3.92
RDF(LCC based N)	3.70	2.72	3.76	4.48
RDF+ 5 T FYM	3.16	2.52	4.09	4.31
SEm±	0.13	CD(*P*=0.05)	0.37	

During the year 2019, the direct seeded method of rice establishment under 100 % RDF nutrient management practice recorded the highest density of *Echinochloa crusgalli* species over other combination but found at par with wet-direct seeded method under nutrient management practices RDF (LCC based N). The lowest density of *Echinochloa crusgalli* was found in wet-direct seeded method under nutrient management practice 75 % RDF + FYM (eqiv. to 25%N). In transplanted method, nutrient management practice RDF (LCC based N) recorded significantly higher density of *Echinochloa crusgalli* over RDF + 5 t FYM nutrient management practice but found at with remaining nutrient management practice. In system of rice intensification method, nutrient management practice RDF (LCC based N) recorded the highest value but found at par with remaining nutrient management practices except 75 % RDF + FYM (eqiv. to 25%N) (Table 2b).

During the year 2019, the highest weed density of *Echinochloa colona* was found in the wet-direct seeded method under nutrient management practices RDF (LCC based N) over remaining nutrient management practices but found at par with nutrient management practice RDF + 5 t FYM. In direct seeded rice method, nutrient management practice RDF + 5 t FYM gave the highest density of *Echinochloa colona* over other practices but found at par with nutrient management practices 100 % RDF and 75 % RDF + FYM (equvi. to 25 % N). In system of rice intensification, nutrient management practice RDF (LCC based N) recorded the highest value but was found at par with remaining nutrient management practices. In transplanting method, nutrient management practices RDF + 5 t FYM but found at par with remaining nutrient management practices (Table 2c).

Table 2b: Interaction effect of different establishment methods and nutrient management practices on weed density of *Echinochloa crusgalli* at 60 DAS/DAT during 2019.

Nutrient management practices (F)	Establishment methods (M)			
	TPR	SRI	DSR	WDSR
100 % RDF	9.85	4.74	23.76	17.95
75 % RDF + FYM (equiv. to 25 % N)	8.92	4.54	17.95	17.67
150% RDF	8.92	5.94	15.54	20.33
RDF(LCC based N)	10.23	6.92	14.61	22.63
RDF+ 5 T FYM	6.49	5.61	17.23	21.15
SEm±	0.80	CD(*P*=0.05)	2.31	

Table 2c: Interaction effect of different establishment methods and nutrient management practices on weed density of *Echinochloa colona* at 60 DAS/DAT during 2019.

Nutrient management practices (F)	Establishment methods (M)			
	TPR	SRI	DSR	WDSR
100 % RDF	10.23	6.56	18.67	5.00
75 % RDF + FYM (equiv. to 25 % N)	10.33	6.33	18.67	12.67
150% RDF	10.98	6.00	16.75	15.00
RDF(LCC based N)	10.65	7.10	15.68	19.63
RDF+ 5 T FYM	11.00	6.00	19.40	18.15
SEm±	0.90	CD(*P*=0.05)	2.59	

Table 3: Effect of establishment method and nutrient management practices on weed density (no. m^{-2}) at 60 DAS/DAT stage of rice.

Treatments	*Cyperus rotundus*		*Caesulia axillaris*		Other Weeds	
	2018	2019	2018	2019	2018	2019
Establishment Methods (M)						
TPR	4.48 (19.56)	4.06 (16.32)	4.49 (19.69)	4.14 (16.69)	3.94 (15.05)	3.36 (11.25)
SRI	2.85 (7.67)	2.67 (6.47)	3.24 (10.00)	2.91 (7.13)	2.91 (7.97)	2.54 (5.97)
DSR	5.07 (25.29)	4.77 (22.29)	5.46 (29.33)	5.05 (26.27)	4.73 (21.91)	4.28 (18.24)
WDSR	4.59 (20.62)	4.60 (20.28)	4.82 (22.81)	4.47 (19.88)	4.14 (16.76)	3.89 (14.76)
SEm±	0.07	0.07	0.07	0.09	0.08	0.09
CD(*P*=0.05)	0.23	0.24	0.26	0.31	0.26	0.30
Nutrient Management Practices (F)						
100 % RDF	4.12 (17.24)	3.83 (14.78)	4.56 (21.14)	4.14 (17.05)	3.92 (15.35)	3.43 (12.35)
75 % RDF + FYM (equiv. to 25 % N)	4.30 (18.89)	4.09 (16.55)	4.40 (19.33)	4.01 (16.08)	3.84 (14.61)	3.42 (11.61)
150% RDF	4.25 (18.18)	4.02 (16.43)	4.47 (20.25)	4.17 (17.58)	3.92 (15.29)	3.51 (12.29)
RDF(LCC based N)	4.27 (18.48)	4.08 (16.18)	4.48 (20.16)	4.13 (17.16)	3.96 (15.66)	3.53 (12.66)
RDF+ 5 t FYM	4.30 (18.63)	4.09 (16.73)	4.60 (21.41)	4.26 (18.41)	4.02 (16.20)	3.70 (13.20)
SEm±	0.07	0.07	0.06	0.08	0.06	0.08
CD(*P*=0.05)	NS	0.21	NS	NS	NS	NS
M × F	NS	NS	NS	NS	NS	NS

Total weed density

Establishment Method: A perusal of data presented in Table 4 showed that system of rice intensification recorded significantly lower total weed density (no. m^{-2}) followed by transplanting method of rice establishment during both the year of study. Significantly higher weed density was recorded under direct seeded rice method followed by wet-direct seeded method during both the year of study. The lowest weed population under system of rice intensification method and transplanted rice method could be due to continuous submergence of the crop which effectively suppressed weed population and germination of weed seeds which decreased the weed dry matter. Similar findings has also been observed by Subramanian *et al*., (2007) and Parameshwari and Srinivasan, (2014). Baloch *et al*., (2006) found that the transplanted plots had lower weed density and biomass than direct-seeded rice plots. Higher weed density and dry weight was detected in direct seeded and wet direct seeded rice methods as compared to transplanting and system of rice intensification technique because both direct seeded and wet direct seeded rice methods provide conducive environment for germination of weed seed. The findings are similar to those of Prakash *et al.,* (1995).

Nutrient management: Data given in Table 4 indicated that different nutrient management practice had non-significant effect on total weed density during 2018. However, during 2019, the highest total weed density was observed under RDF + 5 t FYM which was found at par with 150 % RDF and RDF (LCC based N). Significantly lower total weed density was found under 75 % RDF + FYM (equiv. to 25 % N) which was at par with 100% and 150% RDF. The total weed density was higher in RDF + 5 t FYM may be due to increased availability of nutrients for weed growth and development and also the viable seed present in FYM increased the density of weed. The results confirmed the findings of Patel *et al*., (2018).

Total weed dry weight

Establishment Method: It was evident from data presented in Table 4 that the highest total weed dry weight (g m^{-2}) was registered with direct seeded method followed by wet-direct seeded method which are significantly superior over remaining establishment methods during both the year. The lowest total weed dry weight was registered with system of rice intensification method during both the years. The highest total weed dry weight was recorded in direct seeded rice method as compared to other establishment methods might be due to better conditions for weed seed emergence and its survival. System of rice intensification method resulted in lower total weed dry matter due to continuous submergence of the crop that could have effectively suppressed the weed seed germination and weed population and resulted in lower weed dry weight. These results are in agreement with the findings of Singh *et al*., (2005a); Singh *et al*., (2005b); Kumar *et al*., (2017) and Nazir *et al*., (2020). Further, direct seeded rice gave the highest weed density and dry weight which might be due to failure to maintain flooded conditions in field and non-submergence of crop in the initial stages, as crop and weeds germinate simultaneously so competition exists (Parameshwari and Srinivas, 2014). Transplanted and wet seeded rice resulted in lower weed dry weight mainly because of puddling which recorded lesser emergence of deeply placed weed seeds. These results are in agreement with the findings of Singh *et al*., (2005b).

Nutrient management: Data presented in Table 4 showed that different nutrient management practices significantly influence the total weed dry weight (g m^{-2}) during both the year of study. Application of RDF + 5 t FYM recorded the highest total weed dry weight but found at par with 150 % RDF and RDF (LCC based N) during both the year and 75 % RDF + FYM (equiv. to 25 % N) during 2018.

Table 4: Effect of establishment method and nutrient management practices on total weed density (no. m^{-2}) and total weed dry weight (g m^{-2}) at 60 DAS/DAT stage of rice.

	Total Weed Density (no. m^{-2})		Total Weed Dry Weight (g m^{-2})	
	2018	2019	2018	2019
Establishment Method (M)				
TPR	9.65 (92.62)	8.84 (77.76)	7.49 (55.73)	7.30 (52.87)
SRI	6.87 (46.78)	6.44 (40.98)	5.39 (28.54)	5.32 (27.87)
DSR	11.88 (140.77)	11.15 (123.97)	9.17 (83.85)	9.21 (84.30)
WDSR	10.62 (112.40)	10.52 (110.19)	8.28 (68.15)	8.68 (74.93)
SEm±	0.10	0.10	0.08	0.08
CD(*P*=0.05)	0.35	0.35	0.28	0.28
Nutrient Management Practices (F)				
100 % RDF	9.71 (97.46)	9.12 (86.96)	7.29 (54.58)	7.54 (58.79)
75 % RDF + FYM (equiv. to 25 % N)	9.68 (96.36)	9.11 (85.69)	7.57 (58.78)	7.52 (58.27)
150% RDF	9.76 (98.41)	9.25 (88.41)	7.69 (60.89)	7.64 (60.12)
RDF(LCC based N)	9.75 (97.70)	9.31 (89.59)	7.63 (59.59)	7.69 (60.65)
RDF+ 5 t FYM	9.88 (100.80)	9.39 (91.37)	7.73 (61.49)	7.76 (62.13)
SEm±	0.07	0.07	0.10	0.06
CD(*P*=0.05)	NS	0.19	0.28	0.16
M × F	NS	NS	NS	NS

During 2018, the lowest total weed dry weight was found under 100 % RDF. In 2019, the lowest total weed dry weight was found under 75 % RDF + FYM (equiv. to 25 % N). The total weed dry weight was higher in RDF + 5 t FYM might be due to the emergence of viable seed present in FYM which increased the density of weed which ultimately increased the total weed dry weight. Further, continuous and balanced supply and availability of nutrient increased the weed growth and development which might also have helped in increasing total weed dry weight. The results are in conformity with the findings of Rao *et al*., (2007) and Borah *et al*., (2015).

CONCLUSION

From the results of the present investigation, it was concluded that among the establishment methods, system of rice intensification and among the nutrient management practices, 75 % RDF + FYM (equiv. to 25 % N) recorded the lowest weed density and dry weight of weeds. There is also a need to further study the weed dynamics under different establishment methods and nutrient management practices under different agro-ecological conditions.

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