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IMPACT OF CROP ESTABLISHMENT METHODS AND WEED CONTROL ON WEEDS, INSECT-PEST AND DISEASE INFESTATION IN RICE IN NORTH-WESTERN INDO-GANGETIC PLAINS

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Abstract- Direct-seeded rice (DSR) is an emerging production system in Asia in the face of looming water scarcity, labor scarcity and the energy crisis. Field experiment was conducted at Punjab Agricultural University, Ludhiana during *kharif* 2009 and 2010 to study the effect of establishment methods and weed control treatments on weeds, insect-pest attack, disease infestation and rice productivity. The experiment was laid out in Split Plot Design keeping five establishment methods in main plots namely direct seeding with zero till drill, modified furrow drill, conventional seed cum fertilizer drill, wet-seeding and manual transplanting and four weed control treatments in sub-plots comprising of pre-emergence application of pendimethalin 0.75 kg/ha, sequential application of pendimethalin 0.75 kg/ha and bispyribac sodium 0.025 kg/ha or azimsulfuron 0.02 kg/ha along with one weed free treatment. Weed biomass, disease incidence and grain yield did not vary significantly among different establishment methods. The maximum grain yield was recorded in weed free treatment which was statistically at par (P= 0.05) with sequential use of pendimethalin 0.75 kg/ha with bispyribac 0.025 kg or azimsulfuron 0.02 kg/ha. Post-emergence application of bispyribac 0.025 kg/ha significantly reduced disease incidence and was at par with weed free. The influence of establishment methods and weed control treatments on stem borer and leaf folder attack was not significant (P= 0.05). Thus, rice can be direct seeded with zero till drill, modified furrow drill and conventional drill with no significant effect on insect-pest complex. Weeds influenced sheath blight incidence; sequential spray of pendimethalin 0.75 kg/ha and bispyribac 0.025 kg or azimsulfuron 0.02 kg/ha, depending upon weed flora not only controlled weeds but also helped in managing the sheath blight disease of rice.
Keywords- Direct seeded rice, Disease, Grain yield, Insect-pest, Transplanted rice, Weeds

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Introduction

Rice (*Oryza sativa* L.) is life for more than half of humanity and about 90 % of the world's rice is produced as well as consumed in Asia [1]. To sustain present food self-sufficiency and to meet future food requirements, India has to increase its rice productivity by 3 per cent per annum [2] but the possibility of expanding the area under rice in near future is limited. In the Indo-Gangetic Plains, rice is traditionally transplanted in May/June manually in standing water after puddling. With the advances made in rice-based cropping systems, it has been realized that repeated puddling damaged the soil structure and health [3,4] which adversely affects the soil productivity [5] and can negatively affect the growth and yield of following succeeding wheat crop in rotation [6,7]. Moreover, transplanting is labour intensive (30 person/ha/day) and also cost of labour is rising for transplanting of paddy [8]. There is dire need for change in rice establishment methods to improve productivity, economics and long-term sustainability. Depending upon water and labour scarcity, farmers are changing either their rice establishment methods only (from transplanting to direct seeding in puddled soil [Wet-DSR]) or both tillage and rice establishment methods (puddled transplanting to dry direct seeding in unpuddled soil [Dry-DSR]). DSR is a cost effective alternative leading to similar yields under good weed and water management practices. The alternative tillage and crop establishment are site specific. Some innovative farmers of Punjab state have started growing direct seeded rice adopting different drills with different plant densities which needs standardization. Zero till drill, conventionally used for growing wheat in no-till system should be tested for seeding direct seeded rice. Modified furrow drill put the seeds on slope of ridge (two rows per ridge) in alternate furrows and ridges and has inclined plate mechanism as seed metering system. Conventional seed cum fertilizer drill used especially for dry-seeding of rice has inclined plate seed metering device and placed seeds and fertilizer using an inverted T-type opener.

Resource conservation technologies (RCTs) are also being promoted in rice-wheat cropping systems, however, in absence of weed control, rice yields are reduced by 35-100 per cent in direct seeded/RCTs systems [9]. Identifying herbicides with wide-spectrum weed control ability for efficient and economical weed management is also crucial for improving the potential of direct seeding of rice in the state. Yield losses due to sheath blight of rice caused by *Rhizoctonia solani* (Kuhn) are reported to range from 5.2 to 50.0 %

depending upon environmental conditions, crop stage, cultivation practices and cultivars [10]. Under Punjab conditions, this disease has become prevalent on all the varieties particularly, under favourable conditions such as high doses of nitrogen fertilizers, high humidity and high temperature during summer months. This disease has been noticed in more severe form from the fields where weeds *viz*; *Echinochloa crusgalli*, *Echinochloa colonum* and *Cynodon dactylon* are present in or around the field. In rice, overall yield loss due to insect pests varies from 21 to 51 % [11]. New production technology of crop establishment technique of direct seeding may also bring about drastic changes in insect-pest complex. Amongst insect pests causing severe damage to rice crop, stem borers *viz*; yellow stem borer *Scirpophaga incertulas* (Walker), white stem borer *S. innotata* (Walker), pink stem borer *Sesamia inferens* (Walker); leaf folder *Cnaphalocrocis medinalis* (Guenee) and plant hoppers are the dominating ones. The present experiment was conducted to study the effect of different establishment methods and weed control treatments on crop growth, weeds, insect-pest attack, disease infestation and productivity of rice.

Material and Methods

The field experiment was conducted at Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana (India) during *kharif* season (June-November) of 2009 and 2010. The experimental site is situated in Trans-Gangetic Agro-Climatic zone, representing the Indo-Gangetic Alluvial plains at 30°56' N latitude, 75°52' E longitude and at an altitude of 247 m above mean sea level. Ludhiana is characterized by sub-tropical semi-arid type of climate with hot summers and very cold winters. The maximum temperature above 38°C is common during summer. The total rainfall of 818 and 627.6 mm were received during 2009 and 2010, respectively. Most of the rainfall was received in vegetative phase from 23rd (at sowing time) to 35th standard meteorological week (at 80 days after sowing). The soil of the experimental site was loamy sand (coarse loamy, mixed hyperthermic, Typic Ustipsamments) with normal soil reaction (pH=7.5) and electrical conductivity (0.16 dS/m). The soil was low in organic carbon (0.31 %) and available nitrogen (251.7 kg/ha) and medium in available phosphorus (13.5 kg/ha) and potassium (164.1 kg/ha). The experiment was laid out in Split Plot Design with four replications comprising 5 crop establishment methods in main plots and 4 weed control treatments in sub-plots. Three Dry-DSR methods *viz*; direct seeding with Zero Till Drill (Direct Seeding with ZTD), direct seeding with Modified Furrow Drill (Direct Seeding with MFD), direct seeding with Conventional seed cum fertilizer Drill (Direct Seeding with CD), along with Wet-DSR method *viz;* puddled broadcasted and conventional puddled transplanted were taken. Weed control treatments comprised of pendimethalin 0.75 kg/ha as pre-emergence alone and with follow-up application of bispyribac 0.025 kg or azimsulfuron 0.02 kg/ha and weed free. The drill sowing of rice cv. PAU 201 was done at 20 cm row spacing using treated seed on seed-bed prepared in three respective main plots in first week of June. The sowing was done after calibration of drills at the seed rate of 35 kg/ha. In the fourth establishment technique, primed seed was broadcasted in puddled field (wet seeding) and suspended mud is allowed to settle down and form a protective cover over the seeds sown (same operation was done as practised in nursery sowing). For fifth crop establishment method of puddled transplanting, nursery was raised by sowing on the date of direct seeding and transplanted manually with 30 days old seedlings at 20 cm×15cm spacing in puddled field. Pendimethalin was sprayed within two days of sowing with knap sack sprayer using 500 l/ha water. Bispyribac sodium and azimsulfuron were applied with knapsack sprayer fitted with flat fan nozzle using 375 l/ha of water at 30 days after sowing (DAS) in direct seeded plots and at 30 days after transplanting (DAT) or 60 DAS in puddled transplanting method. Weed free plots were kept free from weeds by hand weeding as and when needed. The recommended package of practice was followed for raising the crop. The data on weeds, crop growth, yield attributing characters, yield and N uptake was recorded. The root-soil cores from 0-15, 15-30, 30-60 and 60-90 cm soil depth at maximum tillering stage (90 DAS) were collected using an iron auger of 7 cm inner diameter, hammered to different soil depth increments from the ground surface. Finally roots were separated after carefully flushing in water with the help of mesh sieve. Dry weight of roots was recorded after drying at 65ºC till constant weight. The ratio of dry weight of roots obtained from the given volume of soil core (volume of 15 cm soil core was 0.0005775 $m^3$and that of 30 cm soil core was 0.001155 m^3) was expressed as root mass density (g/m^3) using the formula:

$$\text{Root density } (g/m^3) = \frac{\text{Weight of roots (g) from given volume of soil}}{\text{Volume of given portion of soil/auger } (m^3)}$$

The disease incidence (%) was recorded from each plot at 60 DAS and calculated by dividing number of infected plants in unit area/ total plants in unit area. The leaf was considered to be damaged by the leaf folder if at least 1/3rd of its area was showing symptoms. Leaf damage was recorded from 5 hills selected at random in each plot at 60 DAS. The observations for total number of leaves per hill and damaged leaves were recorded and per cent damage was worked out. Similarly, observations on stem borer damage (dead heart and white ear) were recorded and per cent damage was also worked out. The harvested produce from the net plot was threshed manually and grain yield and straw yield was recorded in kg. The weed data and percentage values of insect-pest damage and disease infestation were subjected to square root transformation before analysis. Data were subjected to ANOVA using PROC MIXED procedure in SAS version 9.2 (SAS, 2009). Normality, homogeneity of variance, and interactions of treatments and years were tested. The Pooled analysis of two years was done and where the ANOVA indicated treatment effects were significant, means were separated at $P \leq 0.05$ and adjusted with Fisher's Protected Least Significant Difference (LSD) test.

Results and Discussion

Effect of Crop Establishment Methods and Weed Control on Crop Growth

Numerically lower emergence count was observed in wet-DSR establishment method, which might be due to the bird damage as seed was broadcasted on surface itself. At 90 DAS, rice crop was significantly taller with direct seeding as compared with puddled transplanted method [Table-1]. This might be due to transplanting shock experienced by the plants in puddled transplanted method. Dry-DSR and wet-DSR produced significantly more crop dry matter as compared with puddled transplanted crop. Direct seeded rice produced significantly more dry matter as compared with the transplanted rice [12,13].

Sequential application of pendimethalin 0.75 kg/ha and bispyribac 0.025 kg or azimsulfuron 0.02 kg/ha resulted in more tillers and crop biomass than single application of pre-emergence herbicide [Table-2]. Pendimethalin 0.75 kg/ha applied as pre-emergence

provided effective control of weeds for initial 20-25 days only, thus crop suffered huge competition thereafter resulting in lower tiller number whereas follow-up spray of bispyribac or azimsulfuron created favourable environment for crop to grow and produce higher number of tillers and thus, the crop dry matter increased.

Irrespective of establishment methods and weed control treatments, almost 90 per cent of roots were confined within top 15 cm soil. There was abrupt fall in root density below this layer [Table-2]. These results are contrary to those reported by [13] who gave the opinion that in the absence of transplanting, the roots of direct seeded rice are located in the shallow surface layer. Moreover, lodging was not observed in direct seeding and conventional transplanted establishment methods. In aerobic direct seeded rice, field drainage increases root's lodging tolerance through improvement in anchoring ability caused by increased soil hardiness and seeding at an optimal depth and distance has not only reduced the seed rate from 80 kg - 200 kg/ha to around 25 kg/ha but has also helped in overcoming lodging problems and spikelet sterility [1]. On the contrary, lodging has been observed more often in direct seeding as compared with transplanted rice crop [14]. Pendimethalin applied as pre-emergence recorded lower root density (almost 9-12 %) as compared to all other herbicidal treatments.

Table 1- Effect of crop establishment methods and weed control on crop emergence, weeds, disease and insect-pest attack

Treatments	Emergence count (No./m²)	Disease incidence (%)	Disease severity (%)	Stem borer damage (%)	Leaf folder damage (%)	Weed count/m²	Weed biomass (g/m²)
Establishment methods							
Direct Seeding with ZTD	139.7	4.0 (20)	1.4 (1)	3.6 (12)	3.8 (13)	1.6 (2)	6.1 (63)
Direct Seeding with MFD	142.4	4.0 (19)	1.4 (1)	3.5 (12)	3.7 (13)	1.6 (2)	6.1 (62)
Direct Seeding with CD	143	4.1 (20)	1.5 (1)	3.6 (12)	3.7 (13)	1.6 (2)	6.1 (62)
Puddled Broadcasted	135.5	4.1 (20)	1.5 (1)	3.6 (12)	3.8 (13)	1.7 (2)	6.4 (70)
Puddled Transplanted	-	3.9 (18)	1.5 (1)	3.5 (11)	3.7 (13)	1.6 (2)	5.9 (59)
LSD (p=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**0.3**
Weed control (kg/ha)							
Pendimethalin 0.75	140	6.0 (36)	1.4 (1)	3.6 (12)	3.8 (13)	2.3 (4)	11.4 (129)
Pendimethalin 0.75 f.b. bispyribac 0.025	139.8	2.1 (3)	1.4 (1)	3.6 (12)	3.7 (13)	1.0 (0)	1.0 (0)
Pendimethalin 0.75 f.b. azimsulfuron 0.02	140.8	6.0 (36)	1.5 (1)	3.5 (11)	3.7 (13)	2.2 (4)	11.2 (124)
Weed free	140.2	2.0 (3)	1.5 (1)	3.6 (12)	3.7 (13)	1.0 (0)	1.0 (0)
LSD (p=0.05)	**NS**	**0.2**	**NS**	**NS**	**NS**	**0.1**	**0.3**
Interaction	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Values represent mean values of two years.

The data was square root transformed and values in the parenthesis are original values.

NS represents non-significant effect.

Table 2- Effect of crop establishment methods and weed control on crop growth parameters

Treatments	Plant height (cm)	Tillers (No./m²)	Crop biomass (g/m²)	Root density (g/m³)			
				0-15 cm	15-30 cm	30-60 cm	60-90 cm
Establishment methods							
Direct Seeding with ZTD	85	531.3	1307.7	2000	95.2	32.55	13.85
Direct Seeding with MFD	86.3	536	1302.6	2078.7	100.2	32.1	14.8
Direct Seeding with CD	85	536.3	1294.8	2037.1	100.75	33.45	15.15
Puddled Broadcasted	84.4	457.1	1237.2	1942.8	90.05	30.85	13.45
Puddled Transplanted	75.7	428.3	943.3	2019.15	98.75	32.65	14.55
LSD (p=0.05)	**3**	**24.6**	**107.8**	**-**	**-**	**-**	**-**
Weed control (kg/ha)							
Pendimethalin 0.75	82.4	402.3	818.3	1830.2	79.4	24.15	10.6
Pendimethalin 0.75 f.b. bispyribac 0.025	84.7	529.5	1350.5	2095.15	100.75	34.3	15.1
Pendimethalin 0.75 f.b. azimsulfuron 0.02	83.3	524	1342.9	2054.7	105.7	33.55	15.2
Weed free	82.8	535.3	1356.7	2083.9	103.3	38	16.7
LSD (p=0.05)	**NS**	**22**	**96.4**	**-**	**-**	**-**	**-**
Interaction	**NS**	**NS**	**NS**	**-**	**-**	**-**	**-**

Values represent mean values of two years.

NS represents non-significant effect.

Effect of Crop Establishment Methods and Weed Control on Weeds

Weed flora of the experimental field consisted of grasses *viz*; *Echinochloa crusgalli* and *E. colonum* and sedges *viz*; *Cyperus iria, C. compressus* and *C. rotundus.* Only rice-associated grass weeds were reported because pre-emergence spray of pendimethalin 0.75 kg/ha was done. At 90 DAS and harvest, weed biomass recorded was statistically similar with application of pendimethalin 0.75 kg

applied as pre-emergence either alone or followed by azimsulfuron 0.02 kg/ha but was significantly more as compared to weed free treatment and application of pendimethalin 0.75 kg as pre-emergence followed by post emergence application of bispyribac 0.025 kg/ha [Table-1]. This might be due to more weed pressure in these treatments.

Effect of Crop Establishment Methods and Weed Control on Disease Infestation

The effect of different crop establishment methods on sheath blight disease incidence was non-significant at 60 DAS [Table-1]. However, disease incidence was significantly affected by different weed control treatments. Disease incidence was more in plots where only pre-emergence application of pendimethalin was done and it was statistically at par with sequential herbicidal treatment of pendimethalin 0.75 kg with azimsulfuron 0.020 kg/ha and was significantly higher as compared with weed free and when sequential application of pendimethalin and bispyribac was done. This might be due to the more population of *Echinochloa* spp. in the former weed control treatments which led to higher disease incidence whereas in later weed control treatments, application of bispyribac completely wiped out the *Echinochloa* spp. which is the alternate host of fungal pathogen [Table-1]. The effective weed control not only controlled weeds but also helped in managing the sheath blight disease of rice [10]. The effect of different crop establishment methods and weed control treatments on disease severity was non-significant.

Effect of Crop Establishment Methods and Weed Control on Insect-pest Attack

Stem borer and leaf folder damage was not affected by different crop establishment methods [Table-1]. But, these results are contrary to earlier researcher that dead heart and white ear infestation was more in case of direct seeding as compared with transplanting method when field was kept unsprayed [15]. Similarly, the influence of different weed control treatments on stem borer and leaf folder damage was not significant. The attack of plant hopper was not observed.

Effect of Crop Establishment Methods and Weed Control on Yield Attributes and Yield

The effective tillers were numerically higher in dry-DSR as compared with transplanting method [Table-3]. Spikelet number is the linear function of plant nitrogen concentration at panicle formation stage and a curvilinear function of crop dry weight. There were fewer grains/panicle in direct seeding methods than puddled transplanted rice. It was observed that, number of grains per panicle was 9 % lower in direct seeded as compared with transplanted rice. Whereas, effective tillers were 9 % higher in direct drilled rice than transplanting method [16] but grains/panicle were lower in direct seeding [12]. Sequential application of two herbicides resulted in significantly more number of effective tillers, panicle length, spikelets/panicle and grain weight/panicle under transplanting rice than direct seeding methods [Table-3]. Dry-DSR and wet-DSR methods produced significantly more straw yield as compared with puddled transplanted method but grain yield was not affected with establishment methods although numerically lower grain and straw yield was observed in wet-DSR. Rice drilled directly in moist seed bed or in dry soil followed by irrigation and broadcasted with or without puddling recorded grain yield at par to puddled transplanting method [17]. However, broadcasting dry seed in puddled field recorded the highest yield as compared with direct seeding using conventional drill and zero drill and broadcasting seeds without puddling and transplanting method [18]. The maximum grain and straw yield was obtained in weed free treatment and was at par with sequential application of two herbicides [Table-3]. These results are in conformity with the findings of [18-20] that where either pre- and post-emergence herbicides or used integrated weed management methods, rice grain yield was significantly more than that of single herbicide treatment.

Table 3- Effect of crop establishment methods and weed control on weed biomass at harvest, yield contributing characters, yield and N uptake

Treatments	Weed biomass (g/m^2)	Effective Tillers/m^2	Panicle length (cm)	Number of spikelets/ panicle	Grain weight/ panicle (g)	Thousand grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Grains Straw N uptake (kg/ha)	
Establishment methods										
Direct Seeding with ZTD	13.0 (320)	276	22.5	110.5	2.5	27.7	5.9	13.4	72.1	83.8
Direct Seeding with MFD	12.9 (318)	278.4	23.2	110.5	2.6	27.7	6	13.4	72.9	84
Direct Seeding with CD	13.0 (319)	281	22.5	111.3	2.6	27.4	6	13.4	73.4	84
Puddled Broadcasted	13.2 (332)	260.6	21.8	108.7	2.4	26.2	5.5	12.8	67.5	80.3
Puddled Transplanted	12.8 (311)	261.6	23.3	119.5	2.8	27.5	6.1	9.7	74.2	62
LSD (p=0.05)	NS	NS	0.7	6.6	0.2	0.7	NS	0.6	NS	6.8
Weed control (kg/ha)										
Pendimethalin 0.75	24.8 (631)	219.7	22	97	2.3	26.1	3.8	8.9	46.7	56.5
Pendimethalin 0.75 f.b. bispyribac 0.025	1.0 (0)	286.6	22.7	116.6	2.7	27.6	6.6	13.7	80.4	85.8
Pendimethalin 0.75 f.b. azimsulfuron 0.02	25.1 (649)	283.5	22.7	116.2	2.7	27.6	6.5	13.7	79.2	85.2
Weed free	1.0 (0)	296.4	23.3	118.6	2.7	27.9	6.7	14	81.8	87.7
LSD (p=0.05)	0.7	15.6	0.6	5.9	0.2	0.6	0.3	0.5	5	4.7
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Values represent mean values of two years.

NS represents non-significant effect.

Effect of Crop Establishment Methods and Weed Control on Nitrogen Uptake by Crop

The direct seeding methods recorded significantly more nitrogen uptake by paddy straw as compared with puddled transplanted crop establishment method. The maximum N uptake by grain and straw was obtained in weed free treatment which was at par with sequential application of pendimethalin and bispyribac or azimsulfuron [Table-3].

Thus, direct seeding is a good alternative of transplanting and rice can be direct seeded with Zero Till Drill, Modified Furrow Drill and Conventional Drill fitted with inclined plate metering device. Weeds can be effectively controlled with sequential application of pendimethalin 0.75 kg/ha and post-emergence herbicides (bispyribac 0.025 kg/ha or azimsulfuron 0.02 kg/ha) at 30days after sowing. New production technology of crop establishment technique of direct seeding has no effect on insect-pest attack and disease infestation.

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References

[1] Kumar V. & Ladha J.K. (2011) *Advances in Agronomy*, 111, 297-413.

[2] Geethalakshmi V., Ramesh T., Palamuthirsolai A. & Lakshmanan (2011) *Archives of Agronomy and Soil Science*, 57(2), 159-66.

[3] Timsina J. & Connor D.J. (2001) *Field Crops Research*, 69, 93-132.

[4] Kukal S.S. & Aggarwal G.C. (2003) *Soil and Tillage Research*, 72, 1-8.

[5] Singh K.K., Jat A.S. & Sharma S.K. (2005) *Indian Journal of Agricultural Science*, 75(7), 396-369.

[6] Kukal S.S. & Aggarwal G.C. (2003) *Soil and Tillage Research* 74, 37-45.

[7] Tripathi R.P., Sharma P. & Singh S. (2005) *Soil and Tillage Research*, 80, 125-137.

[8] Mahajan G., Chauhan B.S. & Gill M.S. (2013) *Field Crops Research*, 144, 89-99.

[9] Kumar V., Bellinder R.R., Gupta R.K., Malik R.K. & Brainard D.C. (2008) *Crop Protection*, 27, 290-301.

[10] Kaur S., Singh S., Mohan C. & Bhullar M.S. (2012) *Journal of Research PAU*, 49(4), 238-241.

[11] Sarao P.S. (2007) *Eco-friendly approaches for the management of rice folder, Cnaphalocrocis medinalis (Guenee) on rice*, Ph.D. Dissertation, Punjab Agricultural University, Ludhiana, 152.

[12] Gill M.S., Kumar A. & Kumar P. (2006) *Indian Journal of Agronomy*, 51(2), 123-127.

[13] Gill M.S., Kumar P. & Kumar A. (2006) *Indian Journal of Agronomy*, 51(4), 283-287.

[14] Zhang Q.C. & Wang G.H. (2002) *Chinese Journal of Rice Science*, 16, 346-350.

[15] Setter T.I., Laureles E.V. & Mazaredo A.M. (1997) *Field Crops Research*, 49, 95-106.

[16] Saharawat Y.S., Singh S., Malik R.K., Ladha J.K., Gathala M., Jat M.L. & Kumar V. (2010) *Field Crops Research*, 116, 260-267.

[17] Bhullar M.S., Walia U.S., Walia S.S., Gill G. & Kaur T. (2012) *Impact of establishment techniques, brown manuring and weed control on productivity of dry seeded rice (Oryza sativa L.) in semi-arid sub-tropical regions of Northern India*. Proceedings of International Conference on Climate Change, Sustainable Agriculture & Public Leadership, NASC, New Delhi.

[18] Walia U.S., Bhullar M.S., Nayyar S. & Sidhu A.S. (2009) *Indian Journal of Weed Science*, 41(1&2), 33-36.

[19] Mahajan G. & Timsina J. (2011) *Archives of Agronomy and Soil Science*, 57(3), 239-250.

[20] Mahajan G., Chauhan B.S. & Johnson D.E. (2009) *Journal of Crop Improvement*, 23(4), 366-382.