

Original Research Article

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Crop and Weed Growth in Direct-Seeded Rice Cultivars as affected by Different Weed Management Practices under Rainfed Conditions of Nagaland, India

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ABSTRACT

Keywords

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Studies were conducted during the *kharif* season of 2009 and 2010 to study the growth of local direct-seeded rice cultivars and weeds as affected by different weed management practices under rainfed conditions of Nagaland. Results showed that the cultivars *Kezie* and *Chongloiman* recorded significantly better crop growth and yield attributes with significantly higher grain yields of 27.70 q/ha and 25.01 q/ha during 2009 and 28.27 q/ha and 26.09 q/ha during 2010 respectively. Significantly lower weed population, weed dry weight and weed relative growth rate and higher weed control efficiency were also recorded by the cultivars *Kezie* and *Chongloiman*. Among the weed management treatments, hand weeding at 20 and 40 days after sowing was found to record significantly higher weed control efficiency with significantly lower weed population and dry weight resulting in better crop growth and superior yield attributes and ultimately recording the highest grain yield of 34.21 q/ha and 35.71 q/ha during 2009 and 2010 respectively.

Introduction

Jhum cultivation is one of the major traditional agricultural land use system prevailing in the State of Nagaland. In a typical *Jhum* field, rice is grown as the main crop mixed with other crops and up to 6 to 7 traditional rice cultivars are cultivated in a *Jhum* field. Despite the rich traditional agricultural innovations the productivity of *Jhum* paddy is much lower compared to rice grown under terrace rice cultivation (TRC)

and wet rice cultivation (WRC). During the year 2014-15 the average productivity of *Jhum* paddy was only 1.94 t/ha compared to TRC/WRC with a productivity of 2.69 t/ha (DES, 2015). Of the several reasons attributed for the low productivity of *Jhum* systems in the State, yield losses due to weeds and unavailability of high yielding varieties suited to *Jhum* situations are major constraints which needs immediate research attention. The weed problem is more severe in direct seeded upland rice than transplanted lowland

condition because direct-seeded rice germinates together with weeds, eliminating the “head start” of transplanted seedlings. In the absence of effective weed control options, yield losses are greater in direct seeded rice than in transplanted rice (Rao *et al.*, 2007). Under *Jhum* conditions, farmers rampantly follow uneconomic and environmentally unsafe weed management practices. Hence, there is an urgent need for research in this area in order to develop and standardize good weed management packages for upland farmers. A number of weed management options are available viz., cultural, mechanical, chemical, biological, etc. and based on the available resources integration of diverse technologies is essential in order to manage (Buhler *et al.*, 2000). Hand removal of weeds still remains to be the most practical method for weed control in many developing countries. Although back breaking and laborious, hand weeding is quite effective if employed at the right time (Hooda, 2002) and is of particular importance where the terrain and climate are unsuitable for mechanised systems. Chemical weed control has become popular among farmers being the most practical, effective and economical tool of weed management in rice (Barman and Varshney, 2008). However, excessive use of herbicides causes environmental pollution and induces the proliferation of resistant weed biotypes. Hence, the combination of direct weed control methods such as herbicide use with subsequent hand weeding would be a more environment-friendly and labour-efficient strategy. Correct choice of cultivar is another important factor essential for maintaining crop quality and yield. Traditional cultivars and landraces grown by local farmers have been selected and preserved over years of experience and interaction with nature and these cultivars are well adapted to the local conditions. Moreover, these landraces contain great genetic variability and can serve as a source for future rice improvement. Another important aspect for choice of cultivar is the

use of competitive cultivars as a component of integrated weed management. Cultural method of weed management like the use of competitive cultivar is an attractive low cost strategy and an efficient way of delivery to farmers (Andrew *et al.*, 2015). The morphological and physiological traits of a strongly competitive crop will enable it to capture resources from a weed and utilize resources more efficiently (Lemerle *et al.*, 2001). Cultivar differences in weed competitiveness have been reported in many crops, including rice (Haefele *et al.*, 2004). Hence, correct choice of cultivars not only ensures crop quality and yield but also helps the crop to get the greatest benefit from other weed control measures. Keeping in view the above facts, the following investigation was conducted to study the effect of cultivars and weed management on crop and weed growth in direct seeded upland rice.

Materials and Methods

The present study was conducted during the *kharif* season of 2009 and 2010 in the experimental farm of School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema campus. The soil of the experimental field was sandy loam, well drained and acidic in reaction with high organic carbon content, low in available N and medium in available P and K. The experiment was laid out in split plot design with three replications. Treatments comprised of four local direct-seeded rice cultivars viz., C₁-*Kezie*, C₂-*Chongloiman*, C₃-*Leikhumo* and C₄-*Kotsala* as main factors and three weed management treatments viz., W₀-Unweeded control, W₁-Hand weeding at 20 and 40 DAS (days after sowing) and W₂-Pre-emergence application of Butachlor @ 1.5 kg a.i./ha + hand weeding at 40 DAS. The cultivars *Chongloiman*, *Leikhumo* and *Kotsala* were tall cultivars with long maturity duration, whereas *Kezie* was a semi-dwarf cultivar with medium

maturity duration. Field preparation was done during the last week of April and May. Well decomposed farmyard manure @ 10 t/ha and NPK @ 40:20:20 kg/ha was uniformly applied to all the plots. The crop was line sown in furrows during the first week of June with a seed rate of 50 kg/ha and maintaining a spacing of 20 cm inter-row and 10 cm inter-plant distance. All other agronomic and cultural practices were kept standard and uniform for all the treatments. The cultivar *Kezie* was harvested during the first week of October while *Chongloiman*, *Leikhumo* and *Kotsala* were harvested during the second week of October. Data on crop growth and yield attributes viz., plant height, number of tillers, leaf area index (LAI), plant dry weight, crop growth rate (CGR), number of panicles, filled grains per panicle, 1000 grain weight and grain yield and weed growth attributes viz., weed population, weed dry weight, relative weed growth rate (RGR) and weed control efficiency (WCE) were recorded to study the response of the crop to the different treatments. Data collected were statistically analyzed by applying the technique of analysis of variance as described by Gomez and Gomez (2010). The significant differences were tested by 'F' test. Critical difference of different groups of treatments and their interactions at 5 per cent probability level were calculated whenever 'F' test was significance.

Results and Discussion

Crop growth

Significant variations in crop growth attributes were recorded among the different cultivars (Table 1 and 2). At 30 and 60 DAS, the cultivars *Leikhumo* and *Kotsala* were at par with each other and recorded significantly taller plants compared to both *Kezie* and *Chongloiman* whereas, at 60 DAS *Chongloiman* was also found to record

significantly taller plants compared to the cultivar *Kezie*. Increased plant height recorded by the cultivars *Leikhumo*, *Kotsala* and *Chongloiman* may be due to increased internode length or due to varietal attributes. Hussain *et al.*, (2014) and Mohammad *et al.*, (2002) also reported increased plant height due to internode elongation and genetic potential of the plant respectively. Number of tillers at 60 DAS was found to be significantly higher for *Kezie* compared to the rest of the cultivars, which may be due to availability of growth resources as well as genetic potential of the cultivar. Production rate and number of tillers per plant depends on variety, availability of water, mineral nutrients and photosynthates (Reddy and Reddy, 2010). Hussain *et al.*, (2014) also reported that higher tiller production was due to genetic variations. Leaf area index (LAI) at flowering was also found to be significantly higher for *Kezie* and *Chongloiman*, which were at par, compared to *Leikhumo* and *Kotsala* which may be due to better utilization of growth resources resulting in higher leaf number and size. Variation in total leaf area of a plant may result from changes in leaf numbers and leaf size (Reddy and Reddy, 2010). Higher tillering exhibited by *Kezie* may also be attributed for higher values of LAI as recorded by the cultivar. Hussain *et al.*, (2014) also reported that *Japonica* varieties showed higher number of panicles/m² due to more number of tillers production by these varieties. Plant dry weight at 60 DAS was significantly higher for *Kezie* and *Chongloiman*, which were at par, compared to both *Leikhumo* and *Kotsala* whereas, at 90 DAS *Chongloiman* recorded significantly higher plant dry weight over the rest of the cultivars. Significantly higher LAI recorded by both *Kezie* and *Chongloiman* and higher number of tillers and plant height recorded by *Kezie* and *Chongloiman* respectively may have resulted in higher dry matter production by the two cultivars.

Hussain *et al.*, (2014) also reported difference in dry matter production of rice due to number of tillers/m² and leaf area index. Owing to higher dry matter production, crop growth rate recorded at 30-60 DAS was also found to be significantly higher for the cultivars *Kezie* and *Chongloiman*. Significant variations in crop growth attributes were also recorded among the different weed management treatments (Table 1 and 2). At both 30 and 60 DAS hand weeding at 20 and 40 DAS (W₁) was found to record the highest plant height, number of tillers, LAI (at flowering) and plant dry weight compared to both application of butachlor @ 1.5 kg a.i./ha + hand weeding at 40 DAS (W₂) and unweeded control (W₀). Mishra (2016) also reported that hand weeding at 20 and 40 DAS proved best with respect to growth parameters viz., plant height, number of tillers, number of leaves, LAI and dry matter accumulation in direct-seeded rice. The treatment W₂ was also found to record significantly higher crop growth attributes viz., plant height, number of tillers, LAI (at flowering) and plant dry weight compared to W₀. Significantly superior crop growth attributes recorded by both W₁ and W₂ may be due to higher weed control efficiency associated with both the treatments which may have resulted in lower crop-weed competition effecting better crop growth and development. Lakshmanon *et al.*, (1984) also reported that higher weed control efficiency favorably induces better crop growth and biomass yield. Crop CGR recorded at 30-60 DAS was also found to be significantly higher for W₁ as compared to both the treatments W₂ and W₀ while, the treatment W₂ was also found to record significantly higher crop CGR over the treatment W₀. Significantly higher plant dry weight recorded by both W₁ and W₂ at both 30 and 60 DAS may be attributed for higher CGR at 30 to 60 DAS as recorded.

Weed growth

Twenty nine (29) weed species were identified from the experimental field out of which broadleaved weeds, grasses and sedges comprised 20, 7 and 2 species respectively. The most dominant weed species observed during both the years were *Digitaria setigera* Roth ex Roem. & Schult, *Cynodon dactylon* (L.) Pers., *Cyperus rotundus* Linn., *Borreria articularis* (L. f.) F. N. Will., *Ipomoea triloba* L. and *Mimosa pudica* L.

Significant variations in weed growth attributes were recorded among the different cultivars (Table 3). At 30 and 60 DAS, *Leikhumo* recorded significantly higher weed population and weed dry weight compared to *Kezie* and *Chongloiman*, which were at par with each other whereas, the cultivar *Kotsala* was found to be at par with the rest of the cultivars with respect to weed population and dry weight at both the stages. The cultivars *Kezie* and *Chongloiman* were found to record significantly higher crop growth rate and dry matter accumulation during the vegetative stages, which may have resulted in early seedling vigor, ground cover and crop establishment thereby giving a competitive edge to the crop resulting in reduced weed growth. Higher tillering associated with *Kezie* and higher LAI associated with both *Kezie* and *Chongloiman* may also have resulted in better light interception, which is a critical factor in the process of interference between crop and weeds. Rice characteristics viz., rapid canopy ground cover during vegetative stage (Fukai, 2000), LAI and tillering (Fischer and Gibson, 2001), early biomass accumulation (Cousens *et al.*, 2003) and early vigor (Zhao *et al.*, 2006) has also been reported to be associated with weed competitiveness by various researchers. Relative growth rate of weeds at 30 to 60 DAS was also found to be significantly lower for the cultivars *Kezie* and *Chongloiman*,

which were at par with each other, which may be due to the fact that both cultivars recorded significantly lower weed dry weight at both stages of observations whereas, *Leikhumo* and *Kotsala* were also at par and recorded significantly higher weed relative growth rate compared to *Kezie* and *Chongloiman*. Owing to significantly reduced weed growth, the cultivar *Chongloiman* recorded the highest weed control efficiency followed by *Kezie* whereas; the lowest weed control efficiency was recorded by the cultivar *Leikhumo*.

Significant variations in weed growth attributes were recorded among the different weed management treatments (Table 4). At all stages of observation, weed population and weed dry weights were recorded to be significantly higher for unweeded control (W_0) compared to the rest of the treatments. Mirza *et al.*, (2007) also reported that weed density was significantly greater in unweeded plots than other treatments. At 30 DAS, hand weeding at 20 and 40 DAS (W_1) was found to record significantly lower weed population and dry weight as compared to application of Butachlor @ 1.5 kg a.i./ha + hand weeding at 40 DAS (W_2). First hand weeding at 20 DAS under the treatment W_1 may have effectively controlled the growth of weeds resulting in lower weed population and dry weight at 30 DAS. Mandal *et al.*, (1986) also reported that hand weeding was most effective in controlling all the three groups of weeds when compared with different herbicides in rice fields, while chemicals were effective in controlling specific group of weeds. Whereas, significantly higher weed growth under the treatment W_2 at 30 DAS may be due to short persistence/decreasing efficiency of butachlor with the lapse of time. Saikia (1991) also reported that the residual effect of pre-emergence herbicide butachlor was too short to provide season long control; a follow up weeding about 30-40 days after crop

emergence was needed to prevent weed emergence. At 60 DAS both the treatments W_1 and W_2 were at par with each other and recorded significantly lower weed population and dry weight compared to the treatment W_0 . Effective control of weeds in upland rice with pre-emergence application of butachlor followed by one hand weeding and two hand weedings at 20 and 40 DAS were also reported by Patel *et al.*, (1997) and Jayadeva *et al.*, (2011) respectively. Relative growth rate of weeds (RGR) at 30 to 60 DAS was found significantly lower for treatment W_0 compared to both the treatments W_1 and W_2 . The treatment W_1 was also found to record significantly lower weed RGR compared to the treatment W_2 . This may be due to the fact that in case of the treatment W_0 the high weed density recorded at 30 DAS may have caused a competition among the weeds resulting in a plateau thereby exhibiting lower relative growth rate at 30 to 60 DAS whereas, treatments W_1 and W_2 recorded significantly lower weed density and dry weight at 30 DAS which may have resulted in lower competition among the weeds and thereby relatively higher accumulation of dry matter and higher relative growth rate. When plants are widely spaced, dry matter of individual plants increase with increase in plant density. Further increase in density, increases the dry matter of individual plants at a diminishing rate. A further increase in plant population results in a plateau i.e. with increase in plant population there is no increase in dry matter per unit area (Reddy and Reddy, 2010). Owing to efficient weed control and significantly reduced weed growth, the highest weed control efficiency (WCE) was recorded by the treatment W_1 followed by W_2 while, the lowest WCE was recorded under the treatment W_0 . Ghosh (2001) also reported that the highest efficiency (76.8%) was derived with manual weeding followed by machete (62.5%).

Table.1 Variation in crop growth attributes of direct-seeded rice as affected by cultivars and weed management

Treatments	Plant height (cm)				Number of tillers (No./m ²)				LAI (Flowering)		CGR (30-60 DAS)	
	30 DAS		60 DAS		30 DAS		60 DAS		2009	2010	2009	2010
	2009	2010	2009	2010	2009	2010	2009	2010				
Cultivars:												
<i>C₁-Kezie</i>	42.07	50.96	82.67	87.43	273.44	282.44	411.53	435.89	1.01	1.13	16.49	16.64
<i>C₂- Chongloiman</i>	44.71	54.51	96.84	104.56	262.89	268.17	341.00	326.22	0.97	1.09	16.51	16.92
<i>C₃- Leikhumo</i>	54.28	60.90	108.26	113.48	247.94	255.61	319.03	311.67	0.74	0.89	13.07	13.76
<i>C₄- Kotsala</i>	55.16	62.96	109.50	115.76	243.44	251.33	323.75	299.06	0.77	0.95	14.77	15.40
SEd _±	3.63	2.31	4.22	4.05	14.93	17.27	28.33	27.05	0.04	0.03	1.24	1.06
CD (P=0.05)	7.91	5.04	9.19	8.83	NS	NS	61.72	58.93	0.08	0.07	2.71	2.30
Weed Management:												
<i>W₀- Unweeded control</i>	41.84	51.44	85.93	94.36	206.63	213.92	211.06	230.83	0.61	0.91	9.76	9.85
<i>W₁- Handweeding at 20 and 40 DAS</i>	56.07	64.99	110.96	115.85	305.00	308.63	457.60	473.92	1.04	1.10	19.62	19.56
<i>W₂- Butachlor @ 1.5 kg a.i/ha + hand weeding at 40 DAS</i>	49.26	55.57	101.05	105.71	259.17	270.63	377.81	324.88	0.97	1.04	16.24	17.63
SEd _±	2.51	1.10	3.32	3.40	10.64	10.22	24.08	20.17	0.09	0.02	0.58	0.87
CD (P=0.05)	5.11	2.24	6.77	6.93	21.68	20.81	49.06	41.09	2.76	0.05	1.19	1.78

NS: Non-significant

Table.2 Variation in crop growth attributes, yield and yield attributes of direct-seeded rice as affected by cultivars and weed management

Treatments	Plant dry weight (g/m ²)				Number of panicles/m ²		Filled grains/panicle		1000-grain weight (g)		Grain yield (q/ha)	
	60 DAS		90 DAS		2009	2010	2009	2010	2009	2010	2009	2010
	2009	2010	2009	2010								
Cultivars:												
<i>C₁-Kezie</i>	843.68	850.93	1176.48	1191.19	246.67	233.61	173.72	166.06	24.73	25.42	25.01	26.09
<i>C₂- Chongloiman</i>	849.72	865.09	1295.85	1310.52	192.61	197.61	191.35	193.19	26.32	27.05	27.70	28.27
<i>C₃- Leikhumo</i>	710.44	731.25	1114.00	1128.07	159.17	161.06	127.32	126.27	23.83	24.48	22.03	23.70
<i>C₄- Kotsala</i>	778.67	800.15	1130.84	1145.38	163.78	160.50	141.89	145.56	23.92	24.55	23.56	25.35
SEd _±	40.00	33.52	39.64	43.92	24.83	17.05	19.40	14.75	1.19	1.12	1.27	1.10
CD (P=0.05)	87.17	73.04	86.37	95.71	54.10	37.14	42.28	32.14	NS	NS	2.76	2.39
Weed Management:												
W ₀ - Unweeded control	602.25	586.29	936.47	931.12	51.25	94.96	104.06	93.68	17.74	19.09	9.07	10.09
W ₁ - Handweeding at 20 and 40 DAS	952.27	989.09	1343.03	1358.66	288.46	257.17	204.61	215.55	29.13	29.64	34.21	35.71
W ₂ - Butachlor @ 1.5 kg a.i/ha + hand weeding at 40 DAS	832.36	860.18	1258.38	1291.59	231.96	212.46	167.04	164.08	27.23	27.39	30.45	31.75
SEd _±	17.44	27.12	30.29	28.83	17.83	8.23	14.19	9.08	0.79	0.96	0.90	0.77
CD (P=0.05)	35.52	55.24	61.71	58.73	36.31	16.76	28.90	18.51	1.61	1.95	1.83	1.58

NS: Non-significant

Table.3 Variation in weed growth attributes as affected by cultivars

Treatments	Weed population (no./m ²)				Weed dry weight (g/m ²)				Weed RGR (30-60 DAS)		WCE	
	30 DAS		60 DAS		30 DAS		60 DAS		2009	2010	2009	2010
	2009	2010	2009	2010	2009	2010	2009	2010				
Cultivars:												
<i>C₁-Kezie</i>	23.63 (557.88)	22.04 (485.26)	19.22 (368.91)	18.14 (328.56)	99.97	94.69	144.16	139.74	0.0176	0.0166	60.61	61.94
<i>C₂- Chongloiman</i>	23.13 (534.50)	21.53 (463.04)	18.57 (344.34)	17.46 (304.35)	97.06	92.03	141.28	136.86	0.0176	0.0164	60.93	62.14
<i>C₃- Leikhumo</i>	26.50 (701.75)	25.12 (630.51)	22.16 (490.57)	21.27 (451.91)	106.05	101.45	157.39	152.80	0.0152	0.0133	60.07	61.33
<i>C₄- Kotsala</i>	24.99 (624.00)	23.47 (550.34)	20.56 (422.21)	19.60 (383.66)	102.41	97.45	149.92	145.50	0.0148	0.0127	60.24	61.59
SEd₊	0.89	0.96	0.94	1.01	2.60	2.51	5.06	4.85	0.0009	0.0008	0.23	0.25
CD (P=0.05)	1.94	2.09	2.05	2.20	5.67	5.47	11.02	10.57	0.0019	0.0018	0.49	0.54

Figures in parenthesis represent original values

Table.4 Variation in weed growth attributes as affected by weed management treatments

Treatments	Weed population (no./m ²)				Weed dry weight (g/m ²)				Weed RGR (30-60 DAS)		WCE	
	30 DAS		60 DAS		30 DAS		60 DAS		2009	2010	2009	2010
	2009	2010	2009	2010	2009	2010	2009	2010				
Weed Management:												
<i>W₀</i>	36.94 (1364.06)	35.50 (1259.75)	41.93 (1757.62)	41.93 (1757.62)	192.34	186.03	416.70	407.38	0.0129	0.0134	0.00	0.00
<i>W₁</i>	10.61 (112.07)	9.61 (91.85)	9.03 (81.04)	9.03 (81.04)	10.46	8.82	13.53	11.00	0.0177	0.0150	92.57	94.64
<i>W₂</i>	26.13 (682.28)	24.01 (575.98)	9.42 (88.24)	9.42 (88.24)	101.32	94.37	14.33	12.80	0.0183	0.0158	88.81	90.61
SEd₊	0.71	0.75	0.75	0.79	2.05	2.08	4.21	4.01	0.0003	0.0003	0.18	0.20
CD (P=0.05)	1.45	1.53	1.53	1.60	4.17	4.24	8.57	8.17	0.0007	0.0006	0.36	0.41

W₀- Unweeded control, W₁- Handweeding at 20 and 40 DAS, W₂- Butachlor @ 1.5 kg a.i/ha + hand weeding at 40 DAS

Figures in parenthesis represent original values; NS: Non-significant

Yield and yield attributes

Significant variations in rice yield and yield attributes were recorded among the different cultivars (Table 2). *Kezie* recorded the highest number of panicles/m², which was significantly higher as compared to *Leikhumo* and *Kotsala* whereas, *Chongloiman* was also found to be at par with the cultivar *Kezie*. Higher number of tillers recorded by *Kezie* may be attributed for higher number of panicles as recorded by the cultivar. Hussain *et al.*, (2014) also reported that higher number of panicles/m² in rice was due to more number of tillers and proportion of effective tillers. The cultivar *Chongloiman* was found to record significantly higher number of filled grains/panicle and grain yield (27.70 q/ha and 28.27 q/ha during 2009 and 2010 respectively) as compared to *Leikhumo* (grain yield - 22.03 and 23.70 q/ha during 2009 and 2010 respectively) and *Kotsala* (grain yield - 23.56 and 25.35 q/ha during 2009 and 2010 respectively) whereas, *Kezie* was also found to record significantly higher number of filled grains/panicle and grain yield (25.01 q/ha and 26.09 q/ha during 2009 and 2010 respectively) compared to the cultivar *Leikhumo*. Variations in yield attributes and grain yield could be due to the genetic potential of the cultivars. Ashrafuzzaman *et al.*, (2009) also found variation in morphological and yield components in different varieties of aromatic rice. Higher dry matter accumulation, LAI and number of filled grains as recorded by both *Chongloiman* and *Kezie* and higher number of tillers and panicles/m² recorded by *Kezie* may also be attributed for higher grain yields as recorded by both the cultivars. Association of growth attributes *viz.*, LAI and dry matter production (Reddy and Reddy, 2010), number of productive tillers (Sheela and Alexander, 1995) and yield attributes *viz.*, percent filled grain (Satapathy and Nanda, 1978), low sterility percentage (Sheela and Alexander,

1995) has also been reported by other researchers. 1000 grain weight was found to be non-significant among the different cultivars. The cultivars *Kezie* and *Chongloiman* were also found to record significantly lower weed population and density and higher weed control efficiency (WCE) as compared to *Leikhumo* and *Kotsala* which may have facilitated efficient utilization of the various growth resources and better expression of yield attributes and thereby resulting in higher grain yield. Lemerle *et al.*, (2001) also stated that the morphological and physiological traits of a strongly competitive crop would enable it to capture resources from a weed, or utilize resources more efficiently.

The different weed management treatments were observed to record significant variations in grain yield and yield attributes (Table 2). Hand weeding at 20 and 40 DAS (W₁) was found to record significantly higher yield attributing characters *viz.*, number of panicles/m², number of filled grains/panicle and 1000 grain weight compared to both application of butachlor @ 1.5 kg a.i./ha + hand weeding at 40 DAS (W₂) and unweeded control (W₀). Whereas, the treatment W₂ was also found to record significantly higher values of the above mentioned yield attributing characters as compared to W₁. Mishra (2016) and Ramana Murthy and Reddy (2013) also reported that hand weeding at 20 and 40 DAS produced the highest number of panicles/m², total number of grains/panicle and number of filled grains/panicle whereas unweeded check recorded the lowest values of these parameters. Significantly lower weed growth as recorded by the treatments W₁ and W₂ may have resulted in increased availability of growth resources to the crop resulting in better crop growth and development thereby exhibiting superior yield attributes. The highest grain yield of 34.21 q/ha during 2009

and 35.71 q/ha during 2010 was recorded by the treatment W₁ which was followed by W₂ (30.45 q/ha and 31.75 q/ha during 2009 and 2010) whereas, W₀ recorded the lowest grain yield during both years (9.07 q/ha and 10.09 q/ha during 2009 and 2010). Ramana Murthy and Reddy (2013) also reported that hand weeding at 20 and 40 DAS recorded the highest grain and straw yields whereas, Pandey (2009) also reported the lowest grain yield under unweeded check. Significantly higher grain yield associated with W₁ and W₂ may be due to better expression of growth and yield components owing to superior weed control. Baharat Bhushan Rao *et al.*, (2000) also reported that grain yield could be associated with production of higher dry matter, greater number of productive tillers, heavier panicle, number of total grains/panicle, sterility per cent and 1000 grains weight.

Among the four cultivars tested, *Chongloiman* and *Kezie* were found to exhibit significantly better crop growth and yield attributes with significantly higher grain yields of 27.70 q/ha and 25.01 q/ha during 2009 and 28.27 q/ha and 26.09 q/ha during 2010 respectively. Significantly lower weed population, weed dry weight and weed RGR and higher weed control efficiency were also recorded by the cultivars *Kezie* and *Chongloiman*. Among the weed management treatments, hand weeding at 20 and 40 days after sowing was found to record significantly higher weed control efficiency with significantly lower weed population and dry weight resulting in better crop growth and superior yield attributes and ultimately recording the highest grain yield of 34.21q and 35.71 q/ha during 2009 and 2010 respectively. Application of butachlor @ 1.5 kg a.i./ha + hand weeding at 40 DAS was also found to record significantly lower weed growth and better crop growth and grain yield (30.45 q/ha and 31.75 q/ha during 2009 and 2010) compared to unweeded control.

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