International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2017; 5(4): 1592-1597
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Received: 03-05-2017
Accepted: 04-06-2017

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New herbicide molecule combination for control of complex weed flora in transplanted rice (*Oryza sativa* L.)

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Abstract
Field experiment was conducted during *kharif,* 2015 and 2016 at Agricultural Research Station, Gangavathi, Koppal District, University of Agricultural sciences, Raichur, Karnataka to study the bio-efficacy of combination of herbicides against complex weed flora and their effect on growth and yield of transplanted rice. The soil was medium deep black clay with medium fertility. At 60 days after transplanting (DAT), among the different herbicide combinations, lower density of grasses, sedges, broad leaf weeds and total weeds (2.96, 3.81, 2.86 and 5.22 / m^2, respectively), dry weed weight (2.20, 2.64, 1.90 and 3.80 g/ m^2, respectively) and higher weed control efficiency (80.69%) was recorded with application of pyrazosulfuron-ethyl 10 % WP 20 g ai/ha at 3 DAT fb chlorimuron ethyl + metsulfuron methyl 20 WP 4 g ai/ha at 25 DAT. Significantly higher total dry matter (81.79 g/plant), number of tillers (481/m^2), number of panicles (381 m^2), grain yield (5.05 t/ha), straw yield (6.02 t/ha) and lower weed index (3.86) was observed with treatment comprising of pyrazosulfuron-ethyl 10 % WP 20 g ai/ha at 3 DAT fb chlorimuron ethyl + metsulfuron-methyl 20 WP 4 g ai/ha at 25 DAT as compared to weedy check which recorded the lowest paddy yield (3.26 t/ha) and higher weed index (38.36 %) but next to hand weeding twice at 25 and 45 DAT. Weedy check treatment noticed significantly highest uptake of total nutrients (98.67 kg/ha) by the weeds as compared to hand weeding twice at 25 and 45 DAT (11.57 kg/ha). Application of pyrazosulfuron-ethyl 10 % WP 20 g ai/ha at 3 DAT fb chlorimuron ethyl + metsulfuron-methyl 20 WP 4 g ai/ha at 25 DAT recorded highest gross returns (Rs. 105738), net returns (Rs. 67462) and benefit cost ratio (2.85) compared to all other treatments under study.

Keywords: Complex weed flora, Combination of herbicides, New molecules, Transplanted, rice, economics and Total nutrient uptake by weeds

Introduction
Staple food for more than 60% of the world population is Rice (*Oryza sativa* L.). In tropical and subtropical regions of the world, it is the most important and extensively grown cereal crop. Major concern for food and nutritional security of more than 60% of Indian population that is dependent on rice is lower productivity of rice (Ram *et al.* 2014). For improving and enhancing productivity of rice restless efforts are being done by the galaxy of scientists under different programmes around the world to evolve varied strategies. The failure in most of the improved crop management practices in case of rice is solely due to not containing of weeds. The total estimated area under rice production in the world is 157.8 m ha with a production of 749.8 m t with an average productivity of 4752 kg ha^{-1} (FAO, 2015). India ranks second in rice production, as it is grown in almost all the states of the country occupying 42.50 m ha area with a production of 100.12 million tones and with a productivity of 2400 kg ha^{-1} (Anonymous, 2015) [2]. Among several reasons for low productivity the one due to weeds is the most important and are the cause of serious concern on reduction of yield in rice production worldwide. Depending on the predominant weed flora, density and on the control methods applied by farmers the losses caused by weeds vary from place to place as they compete with rice for moisture, nutrients, light, temperature and space posing a major threat for increasing productivity (Shilpa Sree *et al.* 2014) [14]. The reduction in yield of rice caused by uncontrolled weed growth is about 33-45% (Manhas *et al.* 2012) [8]. Furthermore, negative correlation with yield exists if any delay in weeding which leads to increased weed biomass. Though, several herbicides are available and are widely used for weed control, their efficacy in reducing the population of all types of weeds is inadequate.

At present, no single approach of either use of herbicides or manual/mechanical weeding is effective in containing weed menace because, persistence of the herbicides in the field is only up to 30 DAT (Balasubramanian *et al.,* 1996) [3] Hence, single application of pre and post emergence herbicide are not resulting in desired level control of weed flora in the transplanted rice ecosystem. Therefore, under such situations, application of herbicide in mixture or in sequence may be useful for broad-spectrum weed control in transplanted rice. Keeping this point in view, a field experiment was carried out to evaluate the effect of combination of herbicides as well as in sequence for controlling complex weed flora in transplanted rice ecosystem.

Materials and Methods

Field experiment was conducted during Kharif, 2015 and 2016 at Agricultural Research Station, Gangavathi, Koppal District Karnataka to study the bio-efficacy of combination of herbicides against complex weed flora and their effect on growth and yield of transplanted rice. The soil type was medium deep black clay with medium fertility. The treatment combinations tested are, Bispyribac-sodium 10 % SC 25 g ai/ha at 25 DAT (T_1), Penoxsulam 24 % SC 22.5 g ai/ha at 15 DAT (T_2), Bispyribac sodium 10 % SC 25 g ai/ha + ethoxysulfuron 15 % WDG 18.75 g ai/ha at 25 DAT (T_3), T1 + chlorimuron ethyl + metsulfuron methyl 20 % WP 4 g ai/ha at 25 DAT (T_4), Pretilachlor 50 % EC 750 g ai/ha at 3 DAT fb ethoxysulfuron 15 % WG 18.75 g ai/ha at 25 DAPT (T_5), Pretilachlor 50 % EC 750 g ai/ha at 3 DAT fb chlorimuron ethyl + metsulfuron methyl 20 % WP 4 g ai/ha at 25 DAT (T_6), Pyrazosulfuron-ethyl 10 % WP 20 g ai/ha at 3 DAT fb chlorimuron ethyl + metsulfuron-methyl 20 % WP 4 g ai/ha at 25 DAT (T_7), Penoxsulam + cyhalofop 6% OD (RM) 135 g ai/ha at 15-20 DAT (T_8), Triafamone + ethoxysulfuron 30 % WG (RM) 60 g ai/ha at 15 DAT (T_9), Pendimethalin 38.7 % CS 750 g ai/ha at 3 DAT fb bispyribac-sodium 10 % SC 25 g ai/ha (T_{10}), Hand Weeding at 25 & 45 DAT (T_{11}), Weedy check (T_{12}), Bensulfuron methyl 0.6 % + Pretilachlor 6 % G 660 g ai/ha at 3 DAT + hand weeding at 25 DAT (T_{13}) and Pyrazosulfuron-ethyl 10 % WP 20 g ai/ha at 3 DAT fb + hand weeding- 25 DAT (T_{14}). The most popular and predominant variety BPT-5204 was planted at a spacing of 20 cm X 10 cm at the seedling age of 30 days, the recommended dose of fertilizer 150:75:75 kg N, P_2O_5 and P_2O_5/ha along with 20 kg $ZnSO_4$ was applied. The crop was planted on 18-08-2015 and harvested on 10-12-2015. The gross and net plot sizes were 6.0 m X 4.0 m and 5.2 m X 3.2 m, respectively. These fourteen treatment combinations were replicated thrice in Randomised Block Design**.**

The data on weed count in a quadrant of 1.0 m x 1.0 m was collected on 60 DAT. From this, the density and dry weight of weeds' category - sedge, grass and broad leaf weeds on 60 DAT was worked out. The data on weeds' density and dry weight were analyzed using transformation of square root of (X + 0.5). At harvest, the data on dry matter accumulation, number of panicles/m^2, grain yield and straw yield were recorded.

Weed index is the reduction in crop yield due to the presence of weeds in comparison with weed free check plot and it was calculated by using the following formula and expressed in percentage.

$$\text{Weed index (\%)} = \frac{X - Y}{X} \times 100$$

Where,

X = Grain yield of weed free plot

Y = Grain yield from the treatment plot for which the weed index has to be workedout.

Similarly, weed control efficiency denotes the magnitude of reduction in weed dry weight due weed control treatments and it was calculated by using the formula given by Patel *et al.* (1987) and expressed in percentage.

$$\text{WCE (\%)} = \frac{DMC - DMT}{DMC} \times 100$$

Where,

WCE = Weed control efficiency (%)

DMC = Dry matter of weeds in unweeded control plot (g/0.25 m^2)

DMT = Dry matter of weeds in treated plot (g/0.25 m^2)

Further, nutrient uptake by weeds and the economics of weed management practices were also worked out by considering the prevailing market prices.

Results and Discussion

Weed flora of the experimental area

The predominant grassy weeds associated with transplanted rice are *Echinochloa colona* (L.), *Echinochloa crusgalli* (L.), *Cynodon dactylon* Pers *and Panicum repens* (L.). *Cyperus iria* (L.), *Cyperus difformis* (L.), *Cyperus rotundus* (L.) and *Fimbristylis miliacea* (L.) among sedges and *Eclipta alba* (L.), *Rotelia densiflora, Marsilea quadrifolia, Sphenoclea zeylanica, Ludwigia parviflora* and *Commelina benghalensis* among broad leaved and aquatic weeds.

Effect on weeds

From the pooled mean at 60 DAT, it was evident that the treatment receiving two hand weeding at 25 and 45 DAT recorded lowest total weed density and dry weight (4.83 / m^2 and 3.47 g/ m^2, respectively) and it was found on par with application of pyrazosulfuron-ethyl 10 % WP 20 g ai/ha at 3 DAT fb chlorimuron ethyl + metsulfuron methyl 20 % WP 4 g ai/ha at 25 DAT (5.52 / m^2 and 3.80 g/ m^2, respectively) as compared to weedy check (11.20 / m^2 and 8.51 g/ m^2, respectively). The next best treatments in the order were penoxsulam + cyhalofop 6% OD (RM) 135 g ai/ha at 15-20 DAT (6.05 / m^2 and 4.20 g/ m^2, respectively), bensulfuron methyl 0.6 % + pretilachlor 6 % G 660 g ai/ha at 3 DAT + hand weeding at 25 DAT (6.25 / m^2 and 4.41 g/ m^2, respectively) and pyrazosulfuron-ethyl 10 % WP 20 g ai/ha at 3 DAT fb + hand weeding at 25 DAT (6.49 / m^2 and 4.57 g/ m^2, respectively). Herbicide combinations were found superior in reducing the density and dry of weeds over single application of herbicide. These results are in line with findings of Singh *et al.* (2012) who reported that density and dry weight of weeds were greatly reduced under two-hand weeding in transplanted rice. Chopra and Chopra (2003) reported significantly reduction in weed density and total weed biomass of Cyperus iria, Echinochloa colona due to the application of Pyrazosulfuron-ethyl at 20 and 25 g/ha. The lower dry matter under Metsulfuron Methyl 10% + Chlorimum Ethyl 10 % might be attributed to restricting of growth of both broad leaved and grassy weeds ultimately reduced both fresh and dry matter accumulation of weeds compared with control. Due to variation in the ability of killing effect of the weeds by the different weedicides, there was variation in this biomass accumulation of weeds (Punabati Heisnam *et al.*,).

Weed control efficiency recorded with hand weeding at 25 & 45 DAT was significantly higher (83.87 %) and was found at par with pyrazosulfuron-ethyl 10 % WP 20 g ai/ha at 3 DAT fb chlorimuron ethyl + metsulfuron-methyl 20 % WP 4 g ai/ha at 25 DAT (80.69%). Penoxsulam + cyhalofop 6% OD (RM) 135 g ai/ha at 15-20 DAT (76.26 %), bensulfuron methyl 0.6 % + pretilachlor 6 % G 660 g ai/ha at 3 DAT + hand weeding at 25 DAT (73.49 %) and pyrazosulfuron-ethyl 10 % WP 20 g ai/ha at 3 DAT fb + hand weeding at 25 DAT (71.53 %) were the other next best treatments with regard to weed control efficiency and were found on par with each other. Chlorimuron ethyl + metsulfuron-methyl was found much effective to control both type of weeds and thus gave higher value of weed control efficiency and recorded the lowest value of weed index (Aman Kumar *et al.*, 2016) [1].

Effect on crop

Hand weeding twice at 25 and 45 DAT recorded significantly the highest total dry matter (84.63.00 g/plant), number of tillers (496/m^2) and number of panicles (392 m^2), lowest weed index (0.00 %) as compared to weedy check but was found on par with treatments comprising of pyrazosulfuron-ethyl 10 % WP 20 g ai/ha at 3 DAT fb chlorimuron ethyl + metsulfuron-methyl 20 % WP 4 g ai/ha at 25 DAT (81.79 g/plant), number of tillers (481/m^2), number of panicles (381 m^2) and lower weed index (3.86 %), penoxsulam + cyhalofop 6% OD (RM) 135 g ai/ha at 15-20 DAT (77.23 g/plant), number of tillers (463/m^2), number of panicles (376 m^2) and lower weed index (1.79 %), bensulfuron methyl 0.6 % + pretilachlor 6 % G 660 g ai/ha at 3 DAT + hand weeding at 25 DAT (78.86 g/plant), number of tillers (449/m^2), number of panicles (371 m^2) and lowest weed index (4.97 %) and pyrazosulfuron-ethyl 10 % WP 20 g ai/ha at 3 DAT fb + hand weeding at 25 DAT (74.96 g/plant), number of panicles (361 m^2), grain yield (4.91 t/ha), straw yield (5.77 t/ha) and lower weed index (6.52 %).

Among the different treatments combination tested. The plot treated with two hand weeding at 25 and 45 DAT noticed significantly higher grain (5.26 t/ha) and straw yield (6.34 t/ha) which was 61.35% higher grain and 66.40 % straw yield, respectively compared to weedy check. Application of pyrazosulfuron-ethyl 10 % WP 20 g ai/ha at 3 DAT fb chlorimuron ethyl + metsulfuron-methyl 20 % WP 4 g ai/ha at 25 DAT recorded grain yield (5.11 t/ha) and straw yield (6.03 t/ha) and was found at par with penoxsulam + cyhalofop 6% OD (RM) 135 g ai/ha at 15-20 DAT with grain (5.09 t/ha) and straw yield (5.97 t/ha), bensulfuron methyl 0.6 % + pretilachlor 6 % G 660 g ai/ha at 3 DAT + hand weeding at 25 DAT with grain (5.00 t/ha) and straw yield (5.87 t/ha) and pyrazosulfuron-ethyl 20 g ai/ha at 3 DAP fb manual weeding (45 DAP) recorded grain yield (4.91 t/ha) and straw yield (5,77 t/ha). Weedy check gave the lowest grain yield (3.15 t/ha) and straw yield (3.81 t/ha), due to severe competition from weeds of all types throughout crop growth period the as evidenced by from weed index (38.83 %).

Again among the herbicides, metsulfuron methyl 10% + chlorimum ethyl 10% resulted overall better performance in all the yield attributes and this might be due to better number of tiller and panicles in these treatments. Metsulfuron methyl 10% + chlorimum ethyl 10% produced the highest number of tillers which was equivalent to the tillers produced by the best treatment and significantly better than control. This also might be due to supply of better growth input to rice by reducing competition of weeds in these treatments. Similar finding was also reported by Sultan Ahmed *et al.* (1986) [17]. Punabati Heisnam *et al.* (2015) [11]. Metsulfuron methyl 10% + chlorimum ethyl 10% (Almix) resulted in maximum grain and straw yield and it proved statistically superior to all other treatment. Sequential application of Butachlor and Anilophos fb 2, 4-D Sodium salt and Bispyribac Sodium and one hand weeding at 25 DAS resulted higher grain yield and profitable rice production (Mallikarjun *et al.*, 2014) [7].

Nutrient uptake by weeds

Weedy check treatment noticed significantly the highest uptake of total nutrients (98.67 kg/ha) by the weeds as compared to hand weeding twice at 25 and 45 DAT (11.57 kg/ha). The other treatments comprising of pyrazosulfuron-ethyl 10 % WP 20 g ai/ha at 3 DAT fb chlorimuron ethyl + metsulfuron methyl 20 % WP 4 g ai/ha at 25 DAT (12.34 kg/ha,) penoxsulam + cyhalofop 6% OD (RM) 135 g ai/ha at 15-20 DAT (13.62 kg/ha), bensulfuron methyl 0.6 % + pretilachlor 6 % G 660 g ai/ha at 3 DAT + hand weeding at DAT 25 (14.85 kg/ha respectively) and pyrazosulfuron-ethyl 10 % WP 20 g ai/ha at 3 DAT fb + hand weeding- 25 DAT (14.86 kg/ha) were found on par with each other and were the next best treatment in sequence after hand weeding twice at 25 and 45 DAT. De Datta and Baltazar (1996) [5] reported as weeds usually grow faster than the crop plants and absorb added nutrient more rapidly and in larger quantities than by crops and thus deprive the supply of nutrients in time to the crop plants. Sudhalakshmi *et al.* (2005) [16] reported that nutrient uptake by weeds was 30 kg N, 10 kg P and 17 kg K per hectare in transplanted rice in clay loam soil of Coimbatore. Puniya *et al.* (2007b) [12] noticed that the highest loss of nutrients (N 42.07, P 10.00 and K 21.80 kg ha-1) occurred with unweeded control due to more density and dry weight of weeds in transplanted rice during *kharif* in silt loam soil of Pantnagar.

Economics

Herbicides alone or in combinations (Rs. 850 to 2963/ha) were cheaper than hand weeding (Rs.8000/ha). Application of pyrazosulfuron-ethyl 10 % WP 20 g ai/ha at 3 DAT fb chlorimuron ethyl + metsulfuron-methyl 20 % WP 4 g ai/ha at 25 DAT recorded the highest benefit cost ratio (2.85) and it was found to be on par with penoxsulam + cyhalofop 6% OD (RM) 135 g ai/ha at 15-20 DAT (2.80), pretilachlor 50 EC 750 g ai/ha at 3 DAT fb chlorimuron ethyl + metsulfuron methyl 20 % WP 4 g ai/ha at 25 DAT (2.61) and bispyribac-sodium 10 SC 25 g ai/ha at 25 DAT+ chlorimuron ethyl + metsulfuron methyl 20 % WP 4 g ai/ha at 25 DAT (2.58). Almix 20 % WP (chlorimuron ethyl + metsulfuron-methyl) @ 4g ha^{-1} as post emergence herbicide at 15 DAT in transplanted rice resulted in highest B: C ratio of 1.41 and maximum net return of Rs. 21, 802 in comparison to hand weeding (Pal *et al.*, 2009) [9].

Table 1: Effect of herbicide mixtures on density of grasses, sedges and broad leaved weeds in transplanted rice

Treatments	Grass weeds popln (No. / m^2)			Sedge weeds popln (No. / m^2)			BL weeds popln (No. / m^2)			Total weeds popln (No. / m^2)		
	60 DAT											
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	4.30 (18.11)	4.55 (20.30)	4.43 (19.20)	4.73 (22.00)	5.12 (25.86)	4.93 (23.93)	4.27 (17.75)	4.49 (19.73)	4.38 (18.74)	7.63 (57.84)	8.13 (65.88)	7.89 (61.86)
T_2	4.33 (18.54)	4.58 (20.73)	4.46 (19.64)	4.81 (22.78)	5.20 (26.64)	5.01 (24.71)	4.36 (18.62)	4.58 (20.60)	4.47 (19.61)	7.76 (59.92	8.25 (67.96)	8.01 (63.94)
T_3	3.84 (14.34)	4.12 (16.53)	3.98 (15.44)	4.27 (17.91)	4.70 (21.77)	4.49 (19.84)	3.68 (13.10)	3.94 (15.08)	3.81 (14.09)	6.76 (45.36)	7.34 (53.38)	7.06 (49.37)
T_4	3.61 (12.57)	3.90 (14.76)	3.76 (13.67)	4.15 (16.74)	4.59 (20.60)	4.37 (18.67)	3.50 (11.87)	3.77 (13.85)	3.64 (12.86)	6.44 (41.18)	7.05 (49.22)	6.75 (45.20)
T_5	4.03 (15.81)	4.29 (18.00)	4.16 (16.91)	4.48 (19.73)	4.90 (23.59)	4.70 (21.66)	4.04 (15.80)	4.28 (17.78)	4.16 (16.79)	7.19 (51.34)	7.73 (59.38)	7.47 (55.36)
T_6	3.96 (15.24)	4.23 (17.43)	4.09 (16.33)	4.33 (18.28)	4.75 (22.14)	4.54 (20.21)	3.91 (14.86)	4.16 (16.84)	4.04 (15.85)	6.98 (48.37)	7.54 (56.41)	7.27 (52.39)
T_7	2.77 (7.18)	3.14 (9.37)	2.96 (8.28)	3.55 (12.17)	4.06 (16.03)	3.81 (14.10)	2.68 (6.71)	3.02 (8.69)	2.86 (7.70)	5.11 (26.05)	5.88 (34.09)	5.52 (30.07)
T_8	3.17 (9.57)	3.50 (11.76)	3.34 (10.66)	3.80 (14.21)	4.29 (18.07)	4.05 (16.14)	3.00 (8.62)	3.32 (10.60)	3.17 (9.61)	5.70 (32.38)	6.38 (40.42)	6.05 (36.40)
T_9	4.29 (18.01)	4.54 (20.20)	4.41 (19.10)	4.70 (21.61)	5.10 (25.47)	4.90 (23.54)	4.17 (17.10)	4.40 (19.08)	4.29 (18.09)	7.55 (56.71)	8.08 (64.74)	7.82 (60.73)
T_{10}	3.74 (13.64)	4.03 (15.82)	3.89 (14.73)	4.24 (17.56)	4.67 (21.42)	4.46 (19.49)	3.57 (12.34)	3.84 (14.32)	3.71 (13.33)	6.62 (43.54)	7.21 (51.57)	6.93 (47.56)
T_{11}	2.49 (5.79)	2.90 (7.98)	2.70 (6.88)	2.95 (8.22)	3.54 (12.08)	3.26 (10.15)	2.29 (4.78)	2.69 (6.76)	2.50 (5.77)	4.39 (18.79)	5.23 (26.82)	4.83 (22.80)
T_{12}	6.41 (40.57)	6.57 (42.76)	6.49 (41.67)	6.89 (47.03)	7.16 (50.89)	7.03 (48.96)	5.82 (33.75)	5.99 (35.73)	5.91 (34.74)	11.01 (121.36)	11.38 (129.39)	11.20 (125.38)
T_{13}	3.22 (10.00)	3.55 (12.19)	3.39 (11.10)	3.88 (14.64)	4.35 (18.50)	4.12 (16.57)	3.22 (9.92)	3.51 (11.90)	3.37 (10.91)	5.90 (34.55)	6.56 (42.59)	6.25 (38.57)
T_{14}	3.39 (11.15)	3.70 (13.35)	3.55 (12.25)	4.04 (15.94)	4.50 (19.80)	4.28 (17.87)	3.35 (10.79)	3.63 (12.77)	3.49 (11.78)	6.17 (37.88)	6.80 (45.91)	6.49 (41.90)
S.Em.±	0.23	0.21	0.21	0.23	0.22	0.22	0.16	0.15	0.16	0.35	0.34	0.35
C.D. (P=0.05)	0.67	0.62	0.64	0.68	0.65	0.65	0.49	0.47	0.48	1.04	1.01	1.03

* Figures in parentheses indicate original values, DAT –Days after transplanting

Table 2: Effect of herbicide mixtures on dry weight of grasses, sedges and broad leaved weeds in transplanted rice

Treatments	Grass weight (g / m^2)			Sedge weight (g / m^2)			BL weeds weight (g / m^2)			Total weeds weight (g / m^2)		
	60 DAT											
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	3.06 (8.94)	3.26 (10.17)	3.16 (9.56)	3.28 (10.29)	3.52 (11.91)	3.40 (11.10)	2.81 (7.41)	3.03 (8.69)	2.92 (8.05)	5.20 (26.61)	5.59 (30.75)	5.40 (28.68)
T_2	3.13 (9.33)	3.32 (10.56)	3.23 (9.95)	3.35 (10.77)	3.59 (12.39)	3.47 (11.58)	2.88 (7.80)	3.09 (9.08)	2.99 (8.44)	5.33 (27.93)	5.70 (32.05)	5.52 (29.99)
T_3	2.77 (7.20)	2.98 (8.43)	2.88 (7.82)	3.05 (8.82)	3.31 (10.44)	3.18 (9.63)	2.53 (5.88)	2.77 (7.16)	2.65 (6.52)	4.73 (21.90)	5.15 (26.03)	4.94 (23.97)
T_4	2.68 (6.72)	2.90 (7.95)	2.79 (7.34)	2.92 (6.72)	3.18 (9.66)	3.05 (8.85)	2.31 (4.89)	2.58 (6.17)	2.45 (5.53)	4.49 (19.65)	4.92 (23.77)	4.71 (21.71)
T_5	2.96 (8.40)	3.17 (9.63)	3.07 (9.02)	3.18 (9.63)	3.42 (11.25)	3.30 (10.44)	2.66 (6.60)	2.89 (7.88)	2.78 (7.24)	5.00 (24.63)	5.40 (28.76)	5.20 (26.70)
T_6	2.93 (8.13)	3.13 (9.36)	3.04 (8.75)	3.15 (9.45)	3.40 (11.07)	3.27 (10.26)	2.62 (6.36)	2.85 (7.64)	2.74 (7.00)	4.94 (23.94)	5.34 (28.08)	5.15 (26.01)
T_7	2.06 (3.75)	2.34 (4.98)	2.20 (4.37)	2.48 (5.67)	2.79 (7.29)	2.64 (6.48)	1.72 (2.49)	2.06 (3.77)	1.90 (3.13)	3.52 (11.91)	4.06 (16.05)	3.80 (13.98)
T_8	2.42 (5.34)	2.66 (6.57)	2.54 (5.96)	2.65 (6.57)	2.94 (8.19)	2.80 (7.38)	1.92 (3.21)	2.23 (4.49)	2.08 (3.85)	3.94 (15.12)	4.44 (19.25)	4.20 (17.19)
T_9	3.02 (8.70)	3.21 (9.93)	3.12 (9.32)	3.23 (9.96)	3.47 (11.58)	3.35 (10.77)	2.71 (6.90)	2.94 (8.18)	2.83 (7.54)	5.09 (25.53)	5.48 (29.67)	5.29 (27.60)
T_{10}	2.73 (6.96)	2.94 (8.19)	2.84 (7.58)	2.98 (8.43)	3.24 (10.05)	3.12 (9.24)	2.45 (5.52)	2.70 (6.80)	2.58 (6.16)	4.63 (20.91)	5.05 (25.03)	4.84 (22.97)
T_{11}	1.79 (2.73)	2.11 (3.96)	1.95 (3.35)	2.34 (4.98)	2.66 (6.60)	2.51 (5.79)	1.51 (1.77)	1.89 (3.05)	1.71 (2.41)	3.16 (9.48)	3.76 (13.62)	3.47 (11.55)
T_{12}	4.86 (23.10)	4.98 (24.33)	4.92 (23.72)	5.43 (29.07)	5.58 (30.69)	5.51 (29.88)	4.26 (17.73)	4.41 (19.01)	4.33 (18.37)	8.39 (69.90)	8.63 (74.02)	8.51 (71.96)
T_{13}	2.51 (5.85)	2.75 (7.08)	2.64 (6.47)	2.76 (7.14)	3.04 (8.76)	2.90 (7.95)	2.11 (3.93)	2.39 (5.21)	2.25 (4.57)	4.17 (16.92)	4.64 (21.04)	4.41 (18.98)
T_{14}	2.63 (6.42)	2.85 (7.65)	2.74 (7.04)	2.82 (6.42)	3.09 (9.09)	2.96 (8.28)	2.22 (4.44)	2.49 (5.72)	2.36 (5.08)	4.33 (18.33)	4.79 (22.46)	4.57 (20.40)
S.Em.±	0.14	0.14	0.13	0.12	0.12	0.11	0.09	0.08	0.09	0.31	0.31	0.30
C.D. (P=0.05)	0.42	0.43	0.40	0.36	0.35	0.34	0.28	0.25	0.27	0.94	0.92	0.91

*Figures in parentheses indicate original values, DAT –Days after transplanting

Table 3: Effect of herbicide mixtures on dry matter accumulation in different parts of transplanted rice

Treatments	DMA in leave (g / plant)			DMA in stem (g / plant)			DMA in panicles (g / plant)			TDMP (g / plant)		
	60 DAT											
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	12.53	13.37	12.95	26.43	27.71	27.07	28.13	29.27	28.70	67.10	70.35	68.73
T_2	12.20	13.03	12.62	25.43	26.71	26.07	27.12	28.28	27.70	64.77	68.02	66.39
T_3	11.70	12.52	12.12	21.10	22.39	21.74	33.80	34.94	34.37	66.60	69.85	68.23
T_4	13.00	13.83	13.42	25.80	27.08	26.44	34.90	36.04	35.47	73.70	76.95	75.33
T_5	11.90	12.73	12.32	21.90	23.17	22.54	31.61	32.75	32.17	65.40	68.66	67.03
T_6	11.50	12.32	11.92	19.80	21.08	20.44	32.50	33.64	33.07	63.80	67.05	65.43
T_7	13.67	14.50	14.08	28.40	29.67	29.04	38.10	39.23	38.67	80.17	83.42	81.79
T_8	12.70	13.54	13.12	25.00	26.28	25.64	37.89	39.05	38.47	75.61	78.84	77.23
T_9	13.53	14.36	13.95	27.77	29.05	28.41	29.80	30.94	30.37	71.10	74.35	72.73
T_{10}	12.13	12.96	12.55	23.10	24.38	23.74	34.00	35.14	34.57	69.23	72.48	70.86
T_{11}	13.67	14.50	14.08	29.03	30.31	29.67	40.30	41.43	40.87	83.00	86.25	84.63
T_{12}	8.27	9.10	8.68	17.87	19.15	18.51	26.93	28.07	27.50	53.06	56.31	54.69
T_{13}	13.33	14.16	13.75	28.00	29.28	28.64	35.90	37.04	36.47	77.23	80.48	78.86
T_{14}	12.63	13.46	13.05	23.90	25.19	24.54	36.80	37.95	37.37	73.32	76.59	74.96
S.Em.±	0.60	0.61	0.61	1.46	1.48	1.47	2.40	2.42	2.44	2.34	2.39	2.40
C.D. (P=0.05)	1.78	0.81	1.82	4.30	4.36	4.34	7.09	7.14	7.19	7.01	7.05	7.08

Table 4: Effect of herbicide mixtures on growth and yield parameters and yield of transplanted rice at ARS, Gangavathi

Treatments	No. of tillers/m^2			No. of panicles/m^2			Grain yield (t / ha)			Straw yield (t / ha)		
	60 DAT											
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	342	348	345	326	331	329	4.31	4.52	4.42	5.09	5.28	5.19
T_2	337	329	340	320	325	323	4.26	4.47	4.37	5.03	5.22	5.13
T_3	390	396	393	347	352	350	4.61	4.82	4.72	5.44	5.63	5.54
T_4	418	424	421	355	360	358	4.74	4.95	4.85	5.59	5.78	5.69
T_5	365	371	368	339	344	342	4.43	4.64	4.54	5.30	5.49	5.40
T_6	378	384	381	341	346	344	4.60	4.81	4.71	5.36	5.55	5.46
T_7	478	484	481	378	383	381	5.06	5.15	5.11	5.92	6.11	6.03
T_8	460	466	463	370	378	376	4.90	5.27	5.09	5.87	6.06	5.97
T_9	352	358	355	333	338	336	4.38	4.59	4.49	5.17	5.36	5.27
T_{10}	405	411	408	353	358	356	4.72	4.93	4.83	5.56	5.75	5.66
T_{11}	493	499	496	389	394	392	5.15	5.36	5.26	6.24	6.43	6.34
T_{12}	305	311	308	220	225	223	3.15	3.36	3.26	3.71	3.90	3.81
T_{13}	446	452	449	368	373	371	4.89	5.10	5.00	5.77	5.96	5.87
T_{14}	429	435	432	358	363	361	4.80	5.01	4.91	5.67	5.86	5.77
S.Em.±	15	16	17	13	14	12	0.13	0.14	0.14	0.19	0.21	0.20
C.D. (P=0.05)	46	48	50	38	41	35	0.38	0.42	0.43	0.57	0.62	0.59

Table 5: Weed control efficiency; weed index and total nutrient depletion by weeds as influenced herbicide mixtures in transplanted rice

Treatments	WCE (%) at 60 DAT			Weed index (%)			Harvest index			Total nutrient uptake by weeds (Kg/ha)		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	61.86	58.40	60.16	16.31	15.11	15.41	0.46	0.49	0.47	53.96	64.54	59.13
T_2	60.04	56.68	58.36	17.28	16.02	16.34	0.46	0.49	0.47	58.18	67.80	60.99
T_3	68.69	64.83	66.76	10.49	9.90	10.10	0.46	0.49	0.47	21.03	29.31	24.54
T_4	71.69	67.68	69.68	7.96	7.43	7.58	0.46	0.49	0.47	14.57	24.75	19.74
T_5	64.92	61.27	63.10	13.98	13.10	13.36	0.46	0.49	0.47	29.07	38.67	33.25
T_6	65.77	62.08	63.93	10.68	10.03	10.24	0.46	0.49	0.48	24.01	33.75	29.39
T_7	83.01	78.36	80.69	1.75	3.78	3.86	0.46	0.49	0.47	8.70	16.59	12.34
T_8	78.46	74.06	76.26	4.85	1.75	1.79	0.46	0.49	0.48	10.69	18.02	13.62
T_9	63.67	60.09	61.88	14.95	13.92	14.20	0.46	0.49	0.47	33.53	42.76	37.28
T_{10}	69.91	66.00	67.95	8.35	8.07	8.24	0.46	0.49	0.47	17.72	26.55	21.45
T_{11}	86.29	81.46	83.87	0.00	0.00	0.00	0.45	0.49	0.47	8.09	15.93	11.57
T_{12}	0.00	0.00	0.00	38.83	37.58	38.36	0.46	0.49	0.47	95.53	107.60	98.67
T_{13}	75.60	71.38	73.49	5.05	4.87	4.97	0.46	0.49	0.47	7.90	19.22	14.85
T_{14}	73.58	69.47	71.53	6.80	6.39	6.52	0.46	0.49	0.47	10.86	19.08	14.86
S.Em.±	1.67	1.84	2.06	2.41	2.85	3.00	0.004	0.005	0.002	2.22	2.49	2.51
C.D. (P=0.05)	4.94	5.44	6.09	7.21	8.39	8.84	NS	NS	NS	6.54	7.35	7.41

Table 6: Economics of rice as influenced by herbicide mixtures in transplanted rice

Treatments	COC (Rs./ha)			Gross returns (Rs./ha)			Net returns (Rs./ha)			B:C		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	39724	40974	40349	94582	90467	92559	54858	49493	52176	2.38	1.97	2.18
T_2	39609	40857	40233	93484	89467	91510	53875	48608	51242	2.36	1.96	2.16
T_3	40599	41849	41224	101162	96400	98781	60563	54551	57557	2.49	2.06	2.28
T_4	40299	41548	40924	104012	98933	101438	63713	57384	60549	2.58	2.13	2.36
T_5	38901	40151	39526	97270	92733	94967	58369	52582	55476	2.50	2.06	2.28
T_6	38601	39851	39226	100888	96200	98543	62287	56349	59318	2.61	2.15	2.38
T_7	38911	40161	39536	110996	103000	105738	72085	62839	67462	2.85	2.29	2.57
T_8	38452	39702	39077	107596	105333	108110	69144	65631	67388	2.80	2.37	2.59
T_9	39111	40361	39736	96116	91800	93957	57005	51436	54221	2.46	2.03	2.25
T_{10}	40452	41702	41077	103568	98533	101016	63116	56831	59974	2.56	2.12	2.34
T_{11}	51313	52563	51938	113142	107200	110170	61829	54637	58233	2.20	1.87	2.04
T_{12}	37636	38886	38261	69118	67133	68091	31482	28247	29865	1.84	1.54	1.69
T_{13}	45175	46425	45800	107306	102067	104723	62131	55642	58887	2.38	1.99	2.19
T_{14}	46350	47600	46975	105336	100200	102768	58986	51600	55293	2.27	1.87	2.07
S.Em.±	-	-	-	2684	2831	2803	2548	2617	2680	0.10	0.09	0.10
C.D. (P=0.05)	-	-	-	7897	8330	8245	7497	7700	7940	0.29	0.28	0.30

Conclusion

Among the different herbicide combination tried, application of pyrazosulfuron-ethyl 10% WP 20 g ai/ha at 3 DAT fb chlorimuron ethyl + metsulfuron methyl 20 % WP 4 g ai/ha at 25 DAT, penoxsulam + cyhalofop 6% OD (RM) 135 g ai/ha at 15-20 DAT, bensulfuron methyl 0.6 % + pretilachlor 6 % G 660 g ai/ha – 3 DAT + hand weeding- 25 DAT and pyrazosulfuron-ethyl 10% WP 20 g ai/ha – 3 DAT fb + hand weeding at 25 DAT were found better in controlling the weeds and resulted in more yield of paddy, apart from saving cost of weed management as compared to hand weeding.

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