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AGRONOMY

Influence of Water Regimes and Weed Management Practices on Weed Densities and Weed growth under System of Rice Intensification (SRI) under Temperate Conditions

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ABSTRACT

Field experiment was conducted at Mountain Research Centre for Field Crops, SKUAST-Kashmir, Khudwani during *Kharif* 2012 and 2013 on slity clay loam soils. The soil of the experimental field was neutral in reaction, testing medium in available P, K and organic carbon content and low in available N. The treatments comprising of three irrigation schedules: alternate wetting and drying (AWD), saturation conditions and continuous flooding and seven weed management practices including four herbicidal treatments (pyrazosulfuron ethyl @ 20 g*a.i.* / ha(3 DAT); cyhalofop butyl @ 80 g*a.i.,* / ha(15 DAT); pyrazosulfuron ethyl 20 g*a.i.* fb cyhalofop butyl 80 g *a.i.,* / ha(3 and 15 DAT); butachlor @ 1.5 kg*a.i.* / ha(3 DAT); three Cono weedings (15, 25 and 35 DAT); along with control and weed free treatment replicated thrice were tested in split plot design to ascertain the most effective herbicide for the control of weeds in rice (*Oryza sativa* L.) under SRI. The data revealed that significant increase in dry matter accumulation by the crop and grain yield was recorded due to the saturation water regime, which was superior to AWD and continuous flooding during both the years of experimentation. However, continuous flooding recorded lower weed densities, dry matter and weed control efficiency. Higher weed index was recorded with saturation water regime. The data on weed management practices revealed that among the herbicides tested,sequential application of pyrazosulfuron-ethyl @ 20 g *a.i.*/ ha(3 DAT) fb cyhalofop-butyl @ 80 g *a.i.*/ ha(15 DAT) produced significantly higher grain yield and dry matter accumulation by the crop comparable to other weed management measures and weedy check treatment. The same treatment also recorded lower weed densities, weed dry matter and weed index but recorded higher weed control efficiency over other weed management practices and control during both the years.

Highlights

- Pyrazosulfuron-ethyl @ 20 g*a.i.* / ha fb cyhalofop-butyl @ 60 g*a.i.* / ha in saturation water regime may be recommended for effective and economical weed management, as the combination proved to be instrumental in enhancing yield and weed control efficiency in the System of Rice Intensification.

Keywords: Water regimes, weed density, weed control efficiency, weed index, SRI

Rice (*Oryza sativa* L.) is the premier food crop of India and therefore, national food security system largely depends on the productivity of rice in different ecosystems. Among the rice growing countries, India stands first in area (36.95 m ha) and second in production (120.6 mt) next to China. However, the average productivity of rice in India is only 3.26 t/ha against the global average of 4.37 tonnes per hectare (FAO STAT 2010). In Jammu and Kashmir State,rice crop is cultivated over an area of 274.0 thousand hectares with a production of around 904.4 thousand tonnes and a productivity of 3.24 t/ha. However, in Kashmir valley the area under rice is 158.0 thousand hectares with a production of 576 thousand tonnes and productivity of 3.645 t/ha (Economic Survey 2013-14).

The existing system of paddy production, particularly green revolution technology is input intensive and favours cash rich farmers. Increasing prices of agricultural inputs prevent poor farmers from completely adopting the modern production technologies (Stoop *et al*. 2002). In order to improve resource use efficiency, it is necessary to address the growing concerns regarding water scarcity, higher fertilizer costs and negative environmental impacts due to the increasing use of agrochemicals for rice production. In such a situation, the system of rice intensification was promoted as an alternative technology and resource management strategy for rice cultivation that may offer the opportunity to boost rice yields with less external inputs (Uphoff and Randriamiharisoa 2002). When rice fields are not flooded continuously and plants are widely spaced as recommended under SRI, weeds get a better chance to grow. Therefore, efficient weed management practices are required under SRI. The higher amount of labour for weeding is one of the most criticized aspects of SRI. So, efforts must be made to eliminate weeds and minimize their competition with rice plants by using less labour for effective weed control methods. Weed control helps to enhance the production environment, thereby allowing more of the inherent capacity of the plant to express itself in higher yields. Therefore, it is essential to control weeds in rice fields for the greater utilization of growth factors by the crop to get higher yield. When fields are not continuously flooded, weed growth becomes a challenging problem and farmers use excess water to check weed growth and to reduce their labour requirements for weed control. Weeding is a deterrent to SRI adoption (Satyanarayana *et al*. 2007). Herbicides have been introduced as they are efficient, practical and cost-effective. They are often the best alternative to control weeds within aleast amount of time and labour.

The Kashmir valley with temperate climate has a unique set of varieties suited to its agro-climatic situation. In spite of this fact, the average yields (3.23 t/ha) are far below the potential yields (9 t/ha) owing to several constraints, the main among them being weed infestation, poor water management and poor adoption of new technologies. Therefore, cost effective and consistent weed management system and appropriate irrigation water management needs to be identified for the system of rice intensification. Hence, an experiment entitled "Influence of Water Regimes and Weed Management Practices on Weed Densities and Weed growth under System of Rice Intensification (SRI) under Temperate Conditions" was conducted to find out the most suitable water and weed management practices for rice cultivation in Kashmir valley.

MATERIALS AND METHODS

Experimental Details and Treatments

Experimental Details: A field experiment was conducted at Mountain Research Centre for Field Crops, SKUAST-Kashmir, Khudwani (33°43′15′′ N, and of 75°5′39′′E and altitude 1,596 m amsl). The site falls in the mid-altitude temperate zone characterized by hot summers and very cold winters with an average annual precipitation of 812 mm (average of past 20 years). The experiment was conducted during *kharif* 2012 and 2013 on silty clay loam soil, which was neutral in pH (6.78), low in nitrogen (215 kg/ha), and medium in available phosphorus (15.0 kg/ha) and potassium (205 kg/ha). The rainfall received during the crop-growing season extending from May to October for 2012 and 2013 was 32 mm and 60 mm, respectively.

Treatments: The experiment comprised of two factors *viz*. 3 Water regimes {Alternate wetting and drying (AWD), saturation and continuous flooding} and 7 weed control methods {Three Cono weedings (15, 25 and 35 DAT); pyrazosulfuron ethyl @ 20 g*a.i.* / ha (3 DAT); cyhalofop butyl @ 80 g*a.i.* / ha (15 DAT); pyrazosulfuron ethyl 20 g*a.i.* fb cyhalofop butyl 80 g *a.i.* / ha (3 and 15 DAT); butachlor @ 1.5 kg*a.i.* / ha (3 DAT); weed free and weedy check} werelaid out in a split plot design with three replications. On the day of transplanting there was no standing water in the field. Transplanting was carried out during the1st week of June forboth the years with a14 days old per hill seedling that was transplanted in a square pattern of 25 cm × 25 cm. Marked ropes at equal distances were used to achieve square planting.All the plots received uniform dose of 120 kg N / ha, 60 kg P_2O_5/ ha and 30 kg K_2O / ha. Whole P, K and half of N were applied as a basal dose before transplantation. The remaining half of N was applied in two equal splits at tillering and panicle initiation, however, FYM @ 10 t / ha was incorporated at the time of layout of the experiment. Crop was irrigated as per the treatments and irrigation was applied early in the morning in the experimental field. Saturation conditions were achieved by frequent application of smaller quantities of water and under AWD water was applied to the soil when the hair line cracks were developing in the soil.

Plant samples: Plants were collected by using a quadrant plot of 0.5 m × 0.5 m (0.25 m2from each plot periodically (30, 60, and 90 DAT) and after sun drying for 3-4 days the samples were oven dried at 60-65^{o}C for 48 hours to a constant weight. The dry weight was recorded in grams and then converted into q / ha. The weeds falling in the quadrant 0.25 m^2 were uprooted from each plot periodically (30, 60 and 90 DAT), identified, counted and expressed as weed number / m^2. The weeds uprooted from the above 0.25 m^2 area from each plot at 30, 60 and 90 DAT for weed count were washed and after sun drying they were oven dried at 60-65^{o}C for 48 hours to a constant weight. The weight was expressed in grams and then converted into g / m^2. Both weed number and weed dry weight were subjected to square root transformation to normalize their distribution. Weed control efficiency and weed index for different weed control treatments were worked out as per the following formulas:

$$WCE = \frac{(WDC - WDT)}{WDC} \times 100$$

Where,

WCE = weed control efficiency

WDC = weed dry weight in control plot

WDT = weed dry weight in treated plot

$$\frac{(Y_{WF} - Y_T)}{Y_{WF}} \times 100$$

Where,

Y_{WF} is the crop yield in weed free plot;

Y_T is the crop yield in treated plot.

The data was statistically analyzed for critical difference as per the standard methods.

Weed Flora: The data showed that the experimental field was infested with grassy, broad leaved weeds as well as sedges. The prominent grassy weeds were *Echinochloa crusgalli*, *E. colona* and *Cynodon dactylon*, the broad leaved weeds were *Ammania baccifera, Marsilea qudrofolia, Monochoria vaginalis* and *Potamogeton distinctus* while the prominent sedges included *Cyperus iria*, *Cyperus defformis* and *Fimbristylis* spp. Though all the type of weeds were present in all the three water regimes, grasses were predominant in alternate wetting and drying (AWD) water regime (80%), sedges were more in saturation water regime (50%), while the broad leaved weeds dominated the flooding water regime (60%).

RESULTS AND DISCUSSION

Crop dry matter and grain yield

Pooled data indicated that saturation water regime significantly increased the dry matter production of rice (Table 1) at all growth stages over AWD and continuous flooding. Saturation water regime also increased the grain yield of rice significantly over flooding water regime, however, AWD was at par with saturation water regime. The higher dry matter and grain yield under saturation water regime during both the years may be attributed to better performance of yield contributing characters due to lower competition and thorough optimum utilization of all inputs, while reduced conditions in flooding water regime may had made lesser availability of inputs resulting in lower rice yields. Non significant effects were recorded by different water regimes in increasing weed index (Table 1), however, during both the years' saturation regime recorded higher weed index when compared to AWD and flooding. This can be a result of higher yields in saturation due to higher uptake of nutrients, higher dry matter accumulation and due to the favourable effects of other growth contributing factors. These results are in conformity with Son *et al.* (2008).

Among the different weed control measures tested, apart from weed free check, sequential application of pyrazosulfuron-ethyl @ 20 g*a.i.* / ha+ cyhalofop-butyl @ 60 g*a.i.* / hathough at par with

Table 1: Crop dry matter, grain yield, weed index and economics of rice as affected by water regimes and weed management practices under SRI

Treatments	Crop dry matter (t/ha)			Grain yield (t/ha)		Weed index (%)		Cost of Cultivation (×10³₹/ ha)	Mean net returns (×10 ³₹/ ha)	B.C ratio
	30 DAT	60 DAT	90 DAT	2012	2013	2012	2013			
Water regimes										
AWD	0.63	9.41	14.26	7.53	7.69	3.68 (15.77)	3.55 (14.78)	39.82	88.14	2.06
Saturation	0.69	9.93	15.12	7.81	7.98	3.70 (15.90)	3.57 (14.95)	44.18	90.58	2.07
Flooding	0.61	9.15	13.83	7.35	7.51	3.48 (14.30)	3.32 (13.27)	45.18	84.00	1.87
SEm ±	0.01	0.11	0.18	0.052	0.054	0.08	0.09	—	—	—
CD (p≤ 0.05)	0.04	0.43	0.70	0.20	0.21	NS	NS	—	—	—
Weed management practices										
Conoweeding (3)	0.57	8.64	14.21	7.49	7.67	4.12 (15.98)	4.00 (14.99)	49.82	81.15	1.63
Pyrazosulfuron - ethyl	0.71	10.79	15.52	8.36	8.56	2.69 (6.27)	2.48 (5.20)	41.32	100.16	2.43
Cyhalofop – butyl	0.55	8.38	13.40	7.16	7.33	4.55 (19.68)	4.44 (18.74)	41.22	85.71	2.09
Pyrazosulfuron fb Cyhalofop	0.76	11.03	16.25	8.54	8.74	2.24 (4.18)	1.96 (3.08)	41.72	101.99	2.45
Butachlor	0.60	8.85	14.62	7.74	7.93	3.74 (13.13)	3.60 (12.10)	41.54	92.48	2.23
Weed free	0.79	11.31	16.76	8.92	9.03	1.00 (0.00)	1.00 (0.00)	52.82	94.84	1.80
Weedy check	0.52	7.48	10.24	4.73	4.85	7.00 (48.02)	6.87 (46.22)	40.82	56.67	1.39
SEm ±	0.02	0.12	0.27	0.05	0.05	0.08	0.09	—	—	—
CD (p≤ 0.05)	0.07	0.36	0.77	0.14	0.15	0.23	0.25	—	—	—

Figures in parenthesis are original values, data subjected to √x+1 transformation

pyrazosulfuron-ethyl @ 20 g*a.i.* / ha significantly improved dry matter production of rice at various growth stages over the other weed control methods (Table 1). The same treatment also increased the grain yield of rice over other weed control measures. The average increase in grain yield by sequential application of pyrazosulfuron-ethyl @ 20 g*a.i.* / hafb cyhalofop-butyl @ 60 g*a.i.* / haover weedy check and butachlor was 44.6 and 9.4 %, respectively. Higher grain yield with sequential application of pyrazosulfuron-ethyl @ 20 g*a.i.* / hafb cyhalofop-butyl @ 60 g*a.i.* / hacould be attributed due to significant improvement in all yield attributes and reduction in crop-weed competition. These results are in close conformity with Kumar (2012), and Ganai *et al.* (2014). Apart from weed free treatment, sequential application of pyrazosulfuron-ethyl @ 20 g*a.i.*, / hafb cyhalofop-butyl @ 60 g*a.i.* / haresulted in lower weed index. This may be due to lower weed densities that resulted in increased uptake of nutrients and thus increased grain yield. The results are in line with Pal *et al.* (2012).

Weed density, weed dry weight and weed control efficiency

The study revealed thatweed density and weed dry weights (Table 2) were significantly lower in the flooding water regime than in saturation and alternate wetting and drying (AWD) during all the crop growth stages. The lower density and dry matter of weeds in flooding water regime at 30, 60 and 90 DAT maybe due to the frequent killing of weeds by continuous submergence. However, under

Table 2: Periodic weed density, weed dry matter, weed control efficiency in rice as affected by water regimes and weed management practices of rice

Treatments	Weed density (No. / m²)			Weed dry matter (g / m²)			Weed control efficiency (%)		
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
Water regimes									
AWD	3.17 (10.09)	4.89 (30.54)	4.78 (26.36)	3.10 (10.79)	4.49 (24.20)	5.42 (36.21)	61.90	59.30	57.94
Saturation	2.94 (9.10)	4.55 (26.25)	4.46 (23.83)	2.89 (9.30)	4.20 (20.88)	5.19 (33.10)	63.00	60.22	58.66
Flooding	2.79 (8.00)	4.29 (23.21)	4.22 (21.16)	2.74 (8.28)	3.94 (18.62)	4.95 (30.27)	64.08	62.22	59.48
SEm ±	0.05	0.05	0.03	0.01	0.05	0.06	—	—	—
CD (p≤ 0.05)	0.21	0.18	0.13	0.04	0.19	0.21	—	—	—
Weed management practices									
Conoweeding (3)	3.54 (11.64)	5.93 (34.31)	5.56 (30.05)	3.47 (11.09)	5.21 (26.30)	6.46 (41.25)	59.6	54.3	52.8
Pyrazosulfuron - ethyl	2.07 (3.46)	2.21 (3.91)	2.06 (4.76)	1.84 (2.38)	2.62 (5.88)	3.70 (9.52)	91.5	89.8	78.9
Cyhalofop - butyl	3.89 (14.25)	6.35 (39.66)	5.95 (34.67)	3.85 (13.82)	5.53 (29.72)	6.88 (46.42)	50.5	49.5	47.5
Pyrazosulfuron fb Cyhalofop	1.96 (2.87)	2.09 (3.40)	1.83 (3.29)	1.73 (1.99)	2.51 (5.30)	3.04 (8.35)	92.8	90.9	80.9
Butachlor	3.62 (12.21)	6.20 (37.74)	5.81 (33.07)	3.16 (8.97)	4.96 (23.69)	6.19 (37.53)	67.4	61.6	55.6
Weed free	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	100	100	100
Weedy check	4.70 (21.25)	8.25 (67.66)	7.69 (58.34)	5.36 (27.88)	7.65 (57.73)	9.50 (89.50)	—	—	—
SEm ±	0.09	0.10	0.09	0.06	0.07	0.09	—	—	—
CD (p≤ 0.05)	0.26	0.28	0.25	0.17	0.21	0.24	—	—	—
WR x WMP	NS	0.50	NS	NS	0.55	NS	—	—	—

Figures in parenthesis are original values, data subjected to √x+1 transformation

AWD water regime, higher dry weight of weeds may be attributed due to luxurious and continuous germination of weeds and keen competition between crop and weeds for growth factor. The data with regard to weed control efficiency (Table 2) revealed that flooding water regime proved efficient in controlling weeds during all the crop growth stages when compared to saturation and AWD water regimes. The lower dry matter of weeds recorded in flooding could have increased efficiency of the treatment in controlling the weeds. Juraimi *et al.* (2011) recorded similar results. All the weed control treatment significantly reduced the weed densities and weed dry weight when compared to weedy check (Table 2). Among weed control measures, apart from weed free check, sequential application of pyrazosulfuron-ethyl @ 20 g*a.i.* / hafb cyhalofop-butyl @ 60 g*a.i.* / hathough at par with the application of pyrazosulfuron-ethyl @ 20 g*a.i.*/ ha significantly reduced weed density and dry matter of weeds over the other weed control treatments. The combination of flooding water regime and sequential application of pyrazosulfuron-ethyl @ 20 g*a.i.* / ha + cyhalofop-butyl @ 60 g*a.i.* / ha though at par with pyrazosulfuron-ethyl @ 20 g*a.i.* / ha recorded significant interaction in reducing the weed densities and weed dry matter at 60 DAT during both the years (Table 3). This may be due to the fact that herbicides not only exhibited lesser toxicity to rice seedling but also controlled the weeds very efficiently. Lower weed index was recorded by the sequential application of pyrazosulfuron-ethyl @ 20 g*a.i.*/ ha + cyhalofop-butyl @ 60 g*a.i.*/ ha. So far, as weed control measures are concerned, apart

Table 3: Interaction effect of irrigation schedules and weed management practices on weed densities and weed dry matter for 60 days after transplanting (Average of two years)

Treatments	Weed densities (per m²) Irrigation schedules				Weed dry matter (per m²) Irrigation schedules			
	AWD	Saturation	Flooding	Mean	AWD	Saturation	Flooding	Mean
Weed management practices								
Conoweeding (3)	6.40 (39.97)	5.91 (33.95)	5.50 (29.23)	5.93 (34.38)	5.61 (30.55)	5.18 (25.79)	4.86 (22.57)	5.21 (26.30)
Pyrazosulfuron - ethyl	2.36 (4.61)	2.18 (3.77)	2.09 (3.37)	2.21 (3.92)	2.86 (7.19)	2.60 (5.77)	2.38 (4.70)	2.62 (5.89)
Cyhalofop - butyl	6.94 (47.23)	6.24 (38.10)	5.88 (33.65)	6.36 (39.66)	5.86 (33.44)	5.50 (29.24)	5.24 (26.50)	5.53 (29.73)
Pyrazosulfuron fb Cyhalofop	2.26 (4.10)	2.07 (3.27)	1.95 (2.81)	2.09 (3.40)	2.75 (6.53)	2.48 (5.17)	2.28 (4.22)	2.51 (5.30)
Butachlor	6.50 (45.52)	6.19 (37.54)	5.92 (34.29)	6.20 (37.78)	5.31 (27.17)	2.45 (23.54)	4.61 (20.38)	4.96 (23.69)
Weed free	1.00 (0.00)	1.00 (0.00)	1.300 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
Weedy check	8.78 (76.63)	8.26 (67.29)	7.74 (59.05)	8.26 (67.66)	8.09 (64.54)	7.58 (56.50)	7.29 (52.15)	7.65 (57.73)
Mean	4.89 (30.58)	4.55 (26.27)	4.30 (23.20)	—	5.99 (24.21)	4.20 (20.88)	3.94 (18.62)	—

CD ($p \leq 0.05$) of weed management practices at same level of Irrigation schedules:0.50 (weed densities); 0.55 (weed dry matter)
CD ($p \leq 0.05$) of irrigation schedules at same level of weed management practices :0.48(weed densities); 0.42 (weed dry matter)

Figures in parenthesis are original values, data subjected to $\sqrt{x+1}$ transformation

from weed free treatment which recorded 100 per cent weed control efficiency, sequential application of pyrazosulfuron-ethyl @ 20 g*a.i.* / ha fb cyhalofop-butyl @ 60 g*a.i.* / hathough at par with application of pyrazosulfuron-ethyl @ 20 g*a.i.* / ha proved to be superior in recording higher weed control efficiency in view of its efficiency in reducing the growth of weeds. This could be attributed due to reduction of weed biomass on the account of effective weed control measures adopted and thus resulted in higher weed control efficiency. The results are in close conformity with those of Kiran *et al.* (2010) and Ganai *et al.* (2014).

Regression and correlation studies

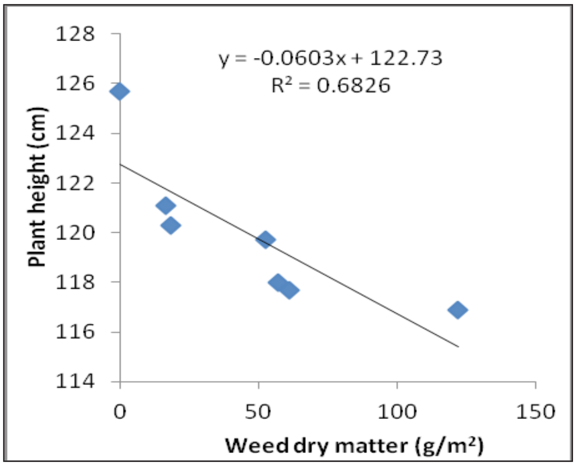
The weed dry matter had highly significant negative correlation with the growth and yield attributes and yields (Fig. 1). The R^2 for weed dry matter with plant height (0.68), LAI (0.98), crop dry matter (0.95), panicles/m² (0.96), grains/panicle (0.96), panicle length (0.95), 1,000-grain weight (0.91), panicle weight (0.97) grain yield (0.96) and straw yield (0.89) was highly significant. The variations in plant height, LAI, crop dry matter, panicles/m², grains/panicle, panicle length, 1,000-grain weight, panicle weight, grain yield and straw yield could be explained to the extent of 68%, 98%, 95%, 96%, 96%, 95%, 91%, 97%, 96% and 89%, respectively.

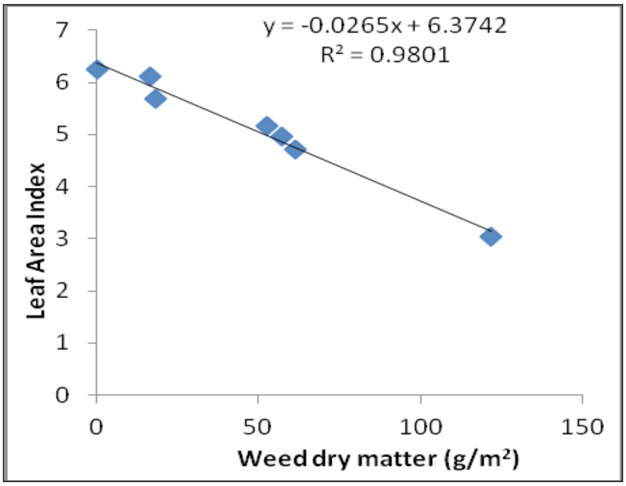
Relative Economics

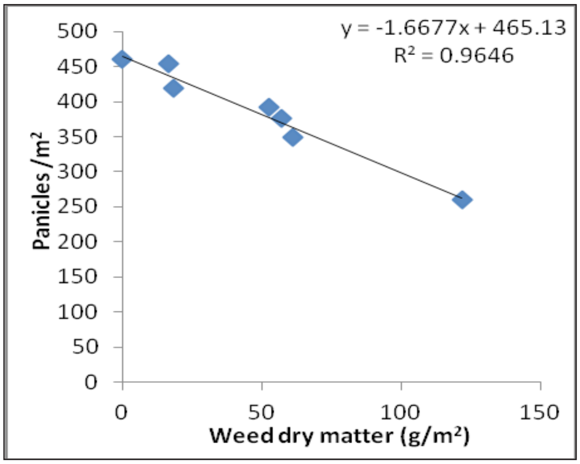
The highest benefit: cost (B: C) ratio (Table 1) was achieved with saturation water regime (2.07) and the sequential application of pyrazosulfuron-ethyl @ 20 g*a.i.*/ hafb cyhalofop-butyl @ 60 g*a.i.*, / ha (2.45). The highest mean net returns were achieved by saturation water regime (₹ 90,580.00) and sequential application of pyrazosulfuron-ethyl @ 20 g*a.i.*/ hafb cyhalofop-butyl @ 60 g*a.i.*, / ha (₹ 1,01,990.00) followed by application of pyrazosulfuron-ethyl @ 20 g*a.i.*, (₹ 1,00,160.00). The results are in line with that Ganai *et al.* (2014).

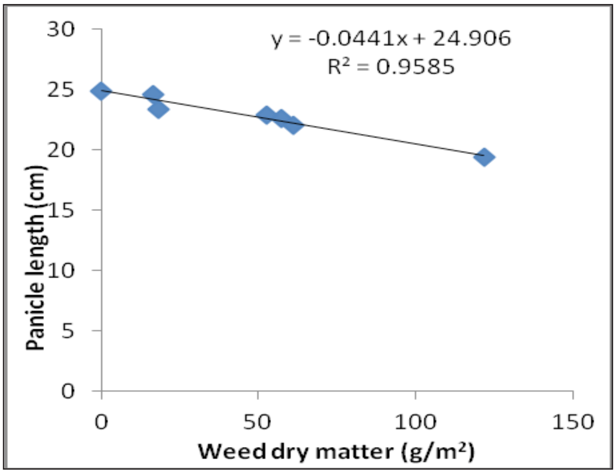
CONCLUSION

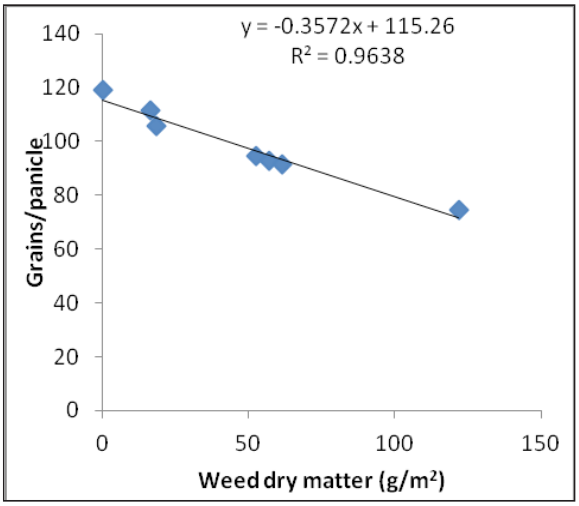
It was concluded that sequential application of

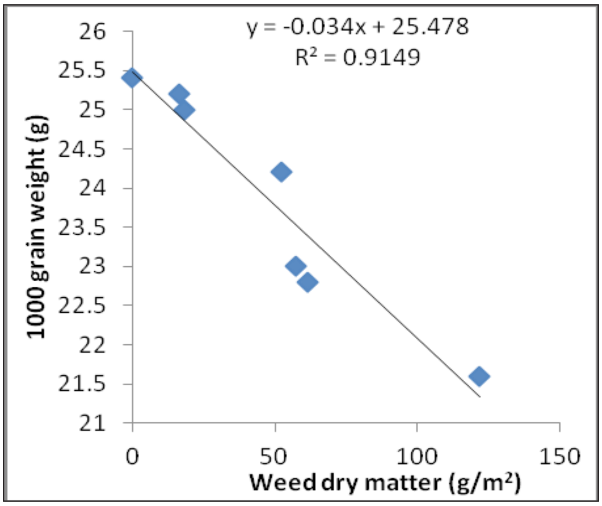

y = -0.0603x + 122.73
R² = 0.6826
Plant height (cm)
Weed dry matter (g/m²)


y = -0.0265x + 6.3742
R² = 0.9801
Leaf Area Index
Weed dry matter (g/m²)


y = -1.6677x + 465.13
R² = 0.9646
Panicles /m²
Weed dry matter (g/m²)


y = -0.0441x + 24.906
R² = 0.9585
Panicle length (cm)
Weed dry matter (g/m²)


y = -0.3572x + 115.26
R² = 0.9638
Grains/panicle
Weed dry matter (g/m²)


y = -0.034x + 25.478
R² = 0.9149
1000 grain weight (g)
Weed dry matter (g/m²)

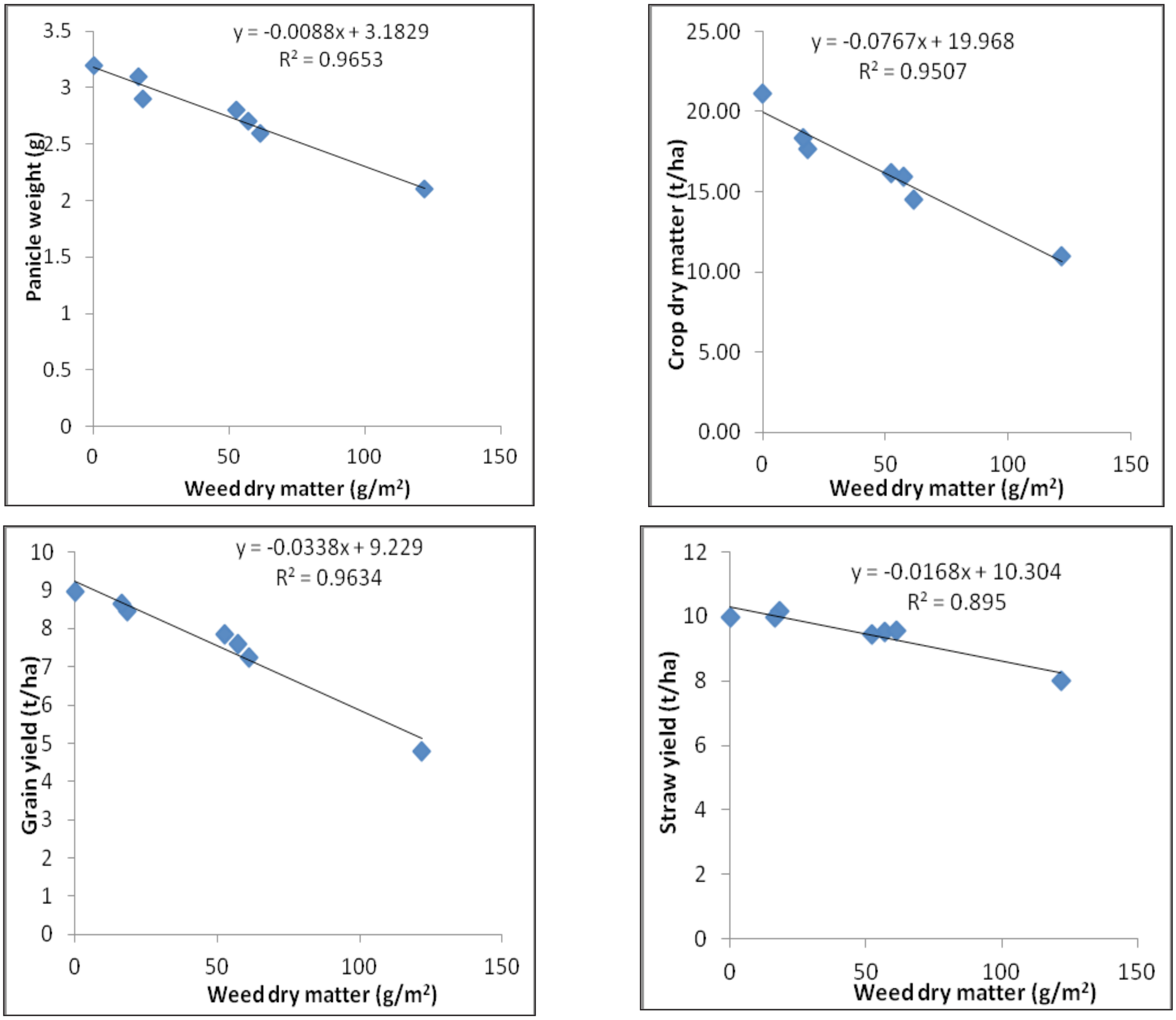


Fig. 1: Relationship between the weed dry matter and various growth and yield attributes of rice

pyrazosulfuron-ethyl @ 20 g*a.i.* / hafb cyhalofop-butyl @ 60 g*a.i.* / hain saturation water regime may be recommended for effective and economical weed control as the combination proved to be instrumental in enhancing yield and weed management efficiency in rice under the System of Rice Intensification under temperate conditions.

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