Research Article

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Effect of weed species on drought tolerant rice genotypes at Sundarbazar, Lamjung, Nepal

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Abstract: Weeds compete with rice for water, nutrients, space and light. The effect of weeds on productivity of rice genotypes were studied at research field of Institute of Agriculture and Animal Science, Lamjung Campus, Lamjung, Nepal in 2016. Eight rice genotypes (IR-87684-18-1-2-3, IR-83388-3-3-140-4, IR-8839-39-1-6-4, IR-87759-7-1-2-3, IR-88966-22-1-1-1, IR-88839-3-1-2-2, IR-88869-2-2-2-2, and Sukhadhan-3) and two weed management practices (Weeded condition and non weeded condition) were studied in randomized complete block design (RCBD) with three replications. Results showed that weeding operation significantly increased the growth traits and final yield of rice genotypes. Non-significant results among tested genotypes were obtained for grain yield and straw yield however the maximum grain yield (3.68 t ha^{-1}) and straw yield (5.99 t ha^{-1}) were found in IR-88839-39-1-6-4 which might be due to highest test grain weight (30.64 g), tallest plant height (105.7m) and lower sterility percentage (21.84%). Similarly, the relative grain yield loss due to weed infestation was 41.8%. The highest grain yield (3.99 t ha^{-1}) and straw yield (6.90 t ha^{-1}) was found in weeded plots compared to non-weeded plots (2.321 t ha^{-1} and 6.43 t ha^{-1}, respectively). Among weed species, *Rotala indica* was found most dominant (1091 m^{-2}) and proportion 18%) followed by *Eriocaulon cinereum* (245.83 m^{-2} and 12%). Interaction effect between variety and weed population showed non-significant results for all growth and yield attributes. The plots having highest number of weed population showed greater loss of rice yield. Thus this study suggests that weeding should be carried out to achieve higher rice production

Keywords: Rice genotypes, grain yield, harvest index, weed population, competition

1 Introduction

Drought reduced rice production by 59-68% and 55-65% in Nakhonratsima and Kalasin provinces of Thailand respectively (Polthanee et al. 2014). Drought and salinity problem have been major problem of agricultural production in world. Drought significantly reduces the yield of crop by reducing the photosynthetic functions by creating deficiency of water content in leaves. Guard cells are found to be losing their turgidity that causes closing of stomatal openings and do not let for transpiration process so to transfer water from root to leaves that reduces the production of photosynthate finally reducing rice yield (Jaleel et al. 2007).

Weed competes with crop plant for nutrients to survive. A study done to know about weed competition against Black Seed (*Nigella Sativa L.*) showed that volume of N,P and K nutrients present in weed exceed by 1.8 to 2 times than in Black Seed (Seyyedi et al. 2016).

Allelopathy generally means the interaction between plants effecting each other in a beneficial or harmful way. Plant produces several kind of secondary metabolites which are responsible for effecting the growth and development of other organisms altering different metabolic processes trough different mechanisms. These compounds are called 'Allelochemicals' due to its interfering nature (Willis 2007). Allelochemicals are responsible for allelopathic interaction between plants (Bogatek and Gniazdowska 2007). Leu et al. (2002) reported that allelochemicals are present in different plant parts that diffuses in atmosphere in volatile forms as well as in form of root exudate by disintegration of leaf litter and bark pieces. Allelochemicals are not only responsible for plant to plant interaction but also between and within plants, microbes, insects and herbivores (Weir et al. 2004). Allelochemicals can inhibit the photosynthetic activity and functioning of exoenzymes in plant. *Myriophyllum spicatum* produces an allelochemical named Tellimagrandin 2 (ß-1,2,3 – tri

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– O – galloyl – 4,6 – (S) – hexahydroxydiphenyl – D-glucose) that alters the functioning of photosystem 2 (PS2) components, electron transport chain, reduces oxygen formation, finally effecting photosynthesis in receiver plants like *Spinach oleracea* (Spinach).

Parasitic weeds decrease rice yield. A parasitic weed, *Rhamphicarpa fistulosa* have shown strong ability to compete both with rice and non - parasitic weeds like *Mitrocarpus villosus* reducing their biomass. In another hand, *Striga assiatica* being potential parasitic weed could not compete with *Mitrocarpus villosus* (Van-Dijk 2014). Goldwasser et al. (2002) and Lee (2007) stated that parasitic weeds invade plant tissue to absorb nutrients, water, and minerals using haustoria. For the haustorial development, certain host plants produces certain germination stimulants identified by particular parasitic weed seeds present in the vicinity of rhizosphere. As a response, parasitic weed releases host recognition factor like 'Strigol' observed in Maize and Porso millet (Siame et al. 1993) Sesquiterpene strigol in Sorghum (Chang et al. 1986) and Sorgolactone in Sorghum (Hauck et al. 1992) induces the development of haustoria that later get attach and invades its tip into host plant tissue (Lee 2007).

CG14 variety of rice have good capacity to suppress the weed population if grown in suitable environmental condition (Toure et al. 2011). The study done in Nigeria shows that NERICA 1 (inter- specific variety of rice) is more weed suppressive than intra-specific Faro 46 (Kolo and Umaru 2012). Weed population and its effect can be reduced using improved weed competitive cultivars of water seeded rice (Gibson et al. 2001).

The main objective of this research was to study about the effects of weed infestation on growth and yield performance of some rice genotypes at the environment of Sundarbazaar Municipality, Lamjung district, Nepal. This study can initiate further researches in detail focusing crop weeds that can help to enhance agricultural productivity of whole Nepal.

2 Materials and methods

The study area is Institute of Agriculture and Animal Science (IAAS), Lamjung Campus situated at Sundarbazar Municipality of Lamjung district in 'Province – 4' of western part of Nepal (CASSD 2015). The experimental materials consisted of two factors i.e. Drought tolerant varieties of rice and weeding practice. Varieties consists of 8 unreleased varieties viz. IR-87684-18-1-2-3, IR-83388-3-3-140-4, IR-8839-39-1-6-4, IR-87759-7-1-2-3, IR-88966-22-1-1-1, IR-88839-3-1-2-2, IR-88869-2-2-2-2, and Sukhadhan-3. Likewise weeding practice included weeding and non-weeding practices. The experiment was performed using two factorial randomized complete block design (RCBD) with three replications. There were 16 treatments per replications. There were three replications (three blocks) for each treatment. So, there were altogether 48 treatments for whole experiment. The area of a single plot was 6m^2 (3m× 2m). The gap width from each side of plot were kept one metre distance for proper isolation and ease for field operations. A small plot was separated within large plot at south-east corner so that remaining area of larger section was 5 m^2 only. The larger and smaller section of plot were weeded and non-weeded plot respectively. This division helped for studying of weeding interaction for each rice varieties and for convenient weed sampling too. The total area of each block was 128 m^2. Since, there were three replications done so, total area of field layout was 384 m^2. Crop were harvested except from sampling rows in weeded section and from whole in non-weeded section. Two hand weeding were practiced to reduce competition between weed and crop for nutrient. First hand weeding was done at 30 DAT which was followed by second hand weeding at 47 DAT. Phenological character like heading up date and maturity period, growth Character like Flag leaf area, Plant height and yield attributing character, Panicle weight, number of effective and non-effective tillers m^{-2}, no. of grains/panicles, Sterility percentage of rice and 1000 test grain weight were studied.

Sterility percentage was calculated by using formula:-

$$\text{Sterility (\%)} = \frac{\text{No. of non-effective grains per panicle}}{\text{No. of effective grains per panicle}} \times 100$$

The grain yield from net plot area was converted to yield per hectare and then the grain were adjusted using moisture adjustment formula:

$$\text{Adjusted grain yield (t ha}^{-1}) = A \times W$$

Where, A is adjustment factor = (M-100)/86,W= Actual grain yield (t ha^{-1})

Likewise, Straw yield was estimated as:

$$\text{Straw yield (t ha}^{-1}) = \text{Biological yield} - \text{Grain yield (t ha}^{-1})$$

After the calculation of grain yield and biological yield, straw yield calculated, harvest Index was calculated using mathematical formula:

$$\text{HI (\%)} = (\text{grain yield}) \times 100 / (\text{grain yield} + \text{straw yield})$$

The relative grain yield loss due to effect of weed was estimated using formula as used by (Haefele et al. 2004):

$$\text{Relative yield loss (\%)} = \frac{\text{Weed free grain yield-Weedy grain yield}}{\text{Weed free grain yield}} \times 100$$

Likewise, abundance of weed and its species were also studied by using dry matter analysis, weed density and frequency analysis.

Weed density and frequency were calculated for each of the treatment plots using formula used by (Nkoa et al. 2015):

$$D_i\ (\text{number m}^{-2}) = (\Sigma Y_i)/(S_a)$$

and

$$F_i\ (\%) = (\Sigma Z_i \times 100)/n$$

Where, D_i = density of species i; ΣY_i = number of individual weed plants of species i contained in the sampling unit (quadrant or field); S_a = Surface area of the sampling unit; F_i = frequency

Value for species i; ΣZi = number of sampling units with species i present; and n = total number of sampling unit surveyed.

For the average weed density computation, all the density of individual species were taken average. Average weed density were calculated for all days interval of observation taken. Likewise, frequency of identified weed species were estimated that was found in experimental plots.

The collected data were analyzed using Genstat 18th edition software. Analysis of variance (ANOVA) was performed and the significant differences between treatments were determined using least significant difference (LSD) test at probability level of 0.01 or 0.05 where the effects of the treatments were significant at 1% or 5% level of probability, respectively (Gomez and Gomez 1984; Kunwar and Shrestha 2014).

Ethical approval: The conducted research is not related to either human or animal use.

3 Results and Discussion

3.1 Agronomic traits

3.1.1 Heading up (50%)

Statistically significant difference in 50% heading was found among genotypes (Table 1). The maximum days required for 50% heading up occurrence was recorded in rice genotype IR-88966-22-1-1-1 to be 99.17 days. IR-88839-3-1-2-2, IR-83388-3-3-140-4 and IR87684-18-1-2-3 were statistically at par to IR-88966-22-1-1-1 showing days of 99.00, 98.67 and 95.58 respectively. Whereas, minimum days required was recorded in IR-8839-39-1-6-4, Sukhadhan-3 and IR-87759-7-1-2-3 to be 93.83, 94 and 94.67 being statistically non-significant respectively. Likewise, Weeding practice showed non-significant difference in 50% heading up which were recorded to be 96.29 and 96.17 in weeded and non-weeded conditions respectively. The variability in heading up occurrence among genotypes are supported by previous researches which has described that such variation may have occurred due to genetic makeup or genotype versus environment interaction rather than effect of weed infestation (Shahid et al. 2012; Balakrishnan et al. 2016). Reproductive phase (Panicle initiation to heading) are however fixed ranging between 30-35 days whatever be the variety or season. It is not effected by photoperiod but can get effected by low temperature, drought and salinity that are responsible to cause sterility in rice (Wopereis et al. 2009). It shows that Interaction effect between tested genotypes and weeding practice show non-significant effect on occurrence of 50% heading up. It means that there was statistically similar performance in 50% heading up occurrence in both of the weeded and non-weeded conditions grown separately.

3.1.2 Maturity date

Statistically significant difference in maturity date was found among genotypes (Table 1). Lowest maturity date was recorded in genotype IR-8839-39-1-6-4 and Sukhadhan-3 with value of 120 days in both which means they are early maturing genotypes. Whereas, IR-83388-3-3-140-4, IR-88839-3-1-2-2 and IR-88966-22-1-1-1 found to be late maturing genotypes with values of 128.78, 129.0, 129.3 days respectively. There was non-significant effect of weeding practice on maturity date. Likewise, Interaction effect of genotypes and weeding practice showed non-significant result. The variability in maturity occurrence among genotypes are supported by previous researches which has described that such variation may have occurred due to genetic makeup or genotype versus environment interaction rather than effect of weed infestation (Shahid et al. 2012; Balakrishnan et al. 2016). Interaction effect showed there was statistically non-significant performance in maturity date in both weeded and non-weeded conditions.

3.1.3 Flag leaf area

The maximum flag leaf area was found in IR-88869-2-2-2-2 followed by IR-88839-3-1-2-2 and IR-87759-7-1-2-3 with value of 26.60, 25.22 and 25.05 cm^{-2} respectively (Table 1). The minimum flag leaf area found to be in Sukhadhan-3 and IR-8839-39-1-6-4 with value of 20.19 cm^{-2} respectively. Effect of weeding practices as well as interaction effect of treatment factors showed non-significant effect. Effect of rice genotypes and environmental relationship may have caused the significant variation in flag leaf area among varieties rather than influence of weed infestation (Shahid et al. 2012; Balakrishnan et al. 2016).

3.1.4 Plant height

Variation in plant height was significant in between tested genotypes (Table 1). Tallest height was found to be tallest plant height for IR-8839-39-1-6-4 and minimum was found in IR-88839-3-1-2-2 to be 105.7 and 98.3 cm respectively. Likewise, weeding practice also showed significant differences in plant height with 103.6 and 100.68 cm respectively. Whereas, interaction effect showed non-significant differences in plant height. Genetic make-up of genotype versus environmental interaction may have influenced the plant height (Shahid et al. 2012; Sunyob et al. 2015). Weedy condition in rice field may have negatively affect the plant height (Cao et al. 2007) because nutrient of rice plant are seized by potential weeds that reduces the growth of rice (Ekeleme et al. 2007; Lee 2007).

3.1.5 Effective tillers per m-2

There were no any significant result observed in effective tillers m^{-2} in between genotypes, weeding practices and interaction effect (Table 1). However, maximum and minimum value was recorded in IR-8839-39-1-6-4 and IR-88839-3-1-2-2 to be 314.2 and 238.3 tillers m^{-2} respectively. Likewise, in weeded and non-weeded condition, tillers m^{-2} recorded were 277.2 and 279.2 respectively. Tiller number could have got significantly reduced due to weed competition (Cao et al. 2007; Mamun 2014; Zi-Chang et al. 2014) but other factors like biotic, abiotic factors or genetic may have interfere its performance (Franks et al. 2007).

3.1.6 Panicle length

Result revealed that there was highly significant differences in panicle length among tested genotypes of rice (Table 2). The longest panicle length was found in genotype IR-87759-7-1-2-3 to be 26.01 cm and shortest in IR-8839-39-1-6-4 to be 23.01 cm respectively. Genotype and environmental interaction and genetic make-up may have affected panicle length of rice (Shahid et al. 2012; Balakrishnan et al. 2016; Ndour et al. 2016). Weed infestation as well as interaction between treatment factors showed non-significant result. Panicle length found in weeded 7 non-weeded condition to be 23.93 and 24.05 cm respectively. Panicle length could have significantly affected by weeding competition but variation also occurs due to genetic make-up of rice genotypes (Hoque et al. 2013).

3.1.7 Panicle weight

There was no significant difference observed in panicle weight among genotypes (Table 2). The maximum and minimum panicle weight were recorded to be 4.208 g and 3.718 g in Sukhadhan-3 and IR-88966-22-1-1-1 respectively. Whereas, weeding practice showed significantly higher panicle weight of 4.250 g in weeded condition than 3.647g in non-weeded condition. Mamun (2014) reported significant reduction in 1000 grain weight which may be due to reduction in dry matter accumulation, photosynthetic rate of flag leaf, root oxidative activity as well as Adenosine Triphosphate (ATPase) in rice grains, finally reducing panicle weight by weed competition (Pandey 2009; Zi-chang et al. 2014). Interaction between genotypes and weeding practice shows statistically similar results in both weeded and non-weeded conditions respectively.

3.1.8 Effective grains per panicle

The result showed that there was significant result in effective grains per panicle among genotypes (Table 2). Maximum and minimum effective grain per panicle was found in IR-88869-2-2-2-2 and IR-8839-39-1-6-4 to be 101.31 and 100.80 grains which are statistically at par with each other. Whereas, the lowest effective grains per panicle was found in IR-88839-3-1-2-2 to be 79.75 grains per panicle. Effective grains per panicle is significantly affected by by genetic ability of rice genotypes (Hoque et al. 2013). Whereas, weeding practice and interaction effect showed non-significant effect in effective grains per panicle. In weeded condition, effective grains per panicle was recorded to be 93.20 and 92.9 grains in weeded and non-weeded conditions respectively. Weeding practice could have significantly enhanced the effect the number of effective grains per panicle (Hoque et al. 2013) but may be genetic make-up and genotype versus environment interaction effected its performance (Shahid et al. 2012; Balakrishnan et al. 2016).

3.1.9 Non-effective grains per panicle

The maximum non-effective grains per panicle was found in IR-83388-3-3-140-4 followed by IR-87759-7-1-2-3, IR-88839-3-1-2-2 and IR-87684-18-1-2-3 with value of 35.88, 35.61, 35.17 and 34.95 grains respectively being statistically at par with each other (Table 2). Likewise, minimum value was recorded in genotypes IR-8839-39-1-6-4 followed by IR-88966-22-1-1-1 and Sukhadhan-3 to be 25.53 and 25.43 grains respectively. Whereas, weeding practice and interaction between treatment factors could not show significant difference in non-effective grains per panicle. It indicates that non-effective grains per panicle may have significantly varied among genotypes due to genetic variation (Hoque *et al.* 2013). Though weed competition could have significantly affected non-effective grains per panicle, or genotype versus environment interaction may have affected its performance (Shahid et al. 2012; Balakrishnan et al. 2016).

3.1.10 Sterility percentage

Statistically significant result was observed in sterility percentage among genotypes (Table 2). Maximum sterility percentage was found in83388-3-3-140-4 followed by IR-87684-18-1-2-3 to be 28.35 and 28.21% respectively being statistically at par with each other. Likewise, minimum sterility percentage was recorded in IR-88966-22-1-1-1 and IR-8839-39-1-6-4 to be 20.94 and 21.84% respectively being statistically non-significant with each other. Sterility percentage mainly depends upon the number of non-effective grains per panicle which depends upon the genetic makeup of rice genotypes (Hoque et al. 2013). Weeding practices and interaction between treatment factors could not show any significant effect on sterility percentage that may be due to variation caused by genotype versus environmental interaction rather than weed competition effect (Shahid et al. 2012; Balakrishnan et al. 2016).

3.2 Yield Attributes

3.2.1 Test grain weight

In between genotypes, significant difference was recorded (Table 3). Maximum test weight was recorded. Maximum test was found in IR-88839-3-1-2-2, followed by IR- 8839-39-1-6-4 to be 30.84 g and 30.64 g respectively statistically at par with each other. Whereas, minimum test weight was found in Sukhadhan-3 and IR-83388-3-3-140-4 to be 26.62 and 28.66 g respectively being statistically at par with each other. Test grain weight get variated among genotypes due to potential traits present according to the genetic features of rice genotypes (Hoque et al. 2013). Likewise, genotype and environmental interrelationship also can cause variation in test grain weight (Islam et al. 2010; Shahid et al. 2012; Balakrishnan et al. 2016).

Chen et al. (2007) has reported that some high yielding hybrid rice have higher light use efficiency, larger panicle size that could use sufficient light for better rate of photosynthesis and dry matter accumulation. This physiological phenomenon could have cause genotypic variation in test grain weight performance. Effect of weeding practice was recorded to be significantly enhancing the test grain weight in rice. Test grain weight in weeded and non-weeded condition found to be 30.43 g and 28.74 g respectively.

Whereas, interaction between genotype and weeding practice could not show the significant result. Several parasitic weeds that absorbs water and nutrients developing its haustoria through roots of rice plant reducing the dry matter accumulation (Goldwasser et al. 2002; Lee 2007). Likewise, allelochemicals produced by different allelopathic weeds alters the rate of photosynthesis by decrease in chlorophyll content (Padhy et al. 2000) and enzymatic activity of crop (Konsula and Kuriakides 2004; Siddiqui and Khan 2011).

3.2.2 Grain yield

Result revealed that there was no significant difference in grain yield among genotypes (Table 3). Maximum grain yield was found in IR-8839-39-1-6-4 and minimum in Sukhadhan-3 to be 3.68 and 2.81t/ha respectively. Though there were so many variation observed in many growth and yield attributes, grain yield couldn't get significantly varied among genotypes. It may be due to ununiformed variation of growth and yield attributes across the genotypes. Although, maximum value of grain yield was recorded in IR-8839-39-1-6-4 could be due to tallest plant height (105.7 cm), higher test grain weight (30.64g), lower sterility (20.94%), lower number of non-effective grains per panicle (25.82), higher number of effective grains per panicle (100.80), longer panicle length (23.01 cm) and maximum effective tillers per m^{-2} (314.2) present but the grain yield value didn't vary in between genotypes tested. Weeding practice showed significant increasement of rice yield where weeded and non-weeded condition showed the grain yield of 3.993and 2.321 t/ha respectively. Weed competition significantly decrease the grain yield due to allelopathic effect (Konsula and Kuriakides 2004; Padhy et al. 2004; Siddiqui and Khan 2011) or due to parasitic effect (Goldwasser et al. 2002; Lee 2007). Relatively yield loss due to weed effect was found to be 41.8%. Similar results was found in previous research (Dobermann and Fairhurst 2000; Ismaila et al. 2013; Mahajan et al. 2014; Rao and Chauhan 2015: Ch. 4). Indirectly, weed can provide habitat for pathogens and insect that are potential to reduce rice yield (Capinera 2005). Whereas, genotype and weeding practice interaction showed non-significant result.

Table 1: Effect of genotypes, weed management practices and their interaction on growth traits of rice genotypes at Lamjung, Nepal, 2016

S.N.	Treatment Combination	50% Heading up (days)	Maturity Date (days)	Flag Leaf Area (cm^2)	Plant Height (cm)	Effective tillers per m^2
Genotypes						
	IR-87684-18-1-2-3	95.58^{a}	125.7^{b}	23.33^{ab}	101.8^{abc}	278.3^{a}
	IR-83388-3-3-140-4	98.67^{a}	128.78^{a}	22.73^{ab}	102.5^{abc}	277.9^{a}
	IR-8839-39-1-6-4	93.83^{c}	124.0^{c}	20.19^{b}	105.7^{a}	314.2^{a}
	IR-87759-7-1-2-3	94.67^{c}	124.7^{bc}	25.05^{a}	103.8^{ab}	295^{a}
	IR-88966-22-1-1-1	99.17^{a}	129.3^{a}	23.86^{ab}	101.7^{abc}	302.9^{a}
	IR-88839-3-1-2-2	99.00^{a}	129.0^{a}	25.22^{a}	98.3^{c}	238.3^{a}
	IR-88869-2-2-2-2	94.92^{bc}	125.0^{bc}	26.60^{a}	101.2^{abc}	262.5^{a}
	Sukhadhan-3	94.00^{c}	124.0^{c}	20.19^{b}	100.0^{abc}	256.2^{a}
F test		***	***	*	*	NS
LSD (0.05)		1.409	1.347	3.715	4.063	49.86
Weeding Practice	1: Weeded	96.29	126.29	23.56	103.6	277.2
	2: Non-weeded	96.17	126.29	23.27	100.68	279.2
F test		NS	NS	NS	*	NS
LSD (0.05)		0.704	0.674	1.858	2.031	24.93
Interaction (Genotypes×Weeding practice)						
F test		NS	NS	NS	NS	NS
LSD (0.05)		1.992	1.905	5.254	5.745	70.52
CV%		1.20%	0.90%	13.50%	3.40%	15.20%
Grand mean		96.23	126.29	23.41	101.87	278.2
SEM		1.195	1.143	3.151	3.445	42.29

*Mean in column followed by similar letters or absence of letters are not significantly different. NS = non-significance, * significance at 0.05 level of significance, ** significance at 0.01 level of significance and ***significance at 0.001 level of significance*

3.2.3 Straw yield, biological yield and harvest index

Straw yield, biological yield and harvest index showed non-significant difference among genotypes (Table 3). Whereas, these were highly significant and higher in weeded condition than no-weeded condition except harvesting index that was non-significant. The straw yield found to be 6.90 t ha^{-1} and 4.11 t ha^{-1}in weeded and non-weeded condition respectively. Likewise, biological yield found to be 9.93 and 6.43 t ha^{-1} in weeded and non-weeded conditions respectively. Harvesting index were 39.81 and 35.94% in weeded and non-weeded conditions respectively. Interaction effect of treatment factor showed non-significant results in each yield parameters. Similar causing factors could be the responsible for significantly enhancement of straw, yield and biological yield in weeded condition as in grain yield as mentioned above.

Weed competition significantly decrease the grain yield due to allelopathic effect (Konsula and Kuriakides 2004; Padhy et al. 2004; Siddiqui and Khan 2011) or due to parasitic effect (Goldwasser et al. 2002; Lee 2007). Similar results was found in previous research (Dobermann and Fairhurst 2000; Ismaila et al. 2013; Mahajan et al. 2014; Rao and Chauhan 2015: Ch. 4). Indirectly, weed can provide habitat for pathogens and insect that are potential to reduce rice straw and biological yield (Capinera 2005). Whereas, genotype and weeding practice interaction showed non-significant result.

3.2.4 Regression and correlation analysis of grain yield

It could be known that test grain weight showed highly significant positive correlation with grain yield that has been described with observed equation of y = 0.2718x-4.8846 and R^2 = 0.2171 (Figure 1). Where, equation showed that a unit increase in test weight will increase grain yield by 0.217 times. R^2 being a coefficient of determination

Table 2: Effect of genotypes, weed management practices and their interaction on yield traits of rice genotypes at Lamjung, Nepal, 2016

S.N.	Treatment Combination	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})	Biological Yield (t ha^{-1})	Harvest Index %	Test Grain Wt. (g)
Genotypes						
	IR-87684-18-1-2-3	3.31[a]	5.967[a]	8.76[a]	37.86[a]	30.23[ab]
	IR-83388-3-3-140-4	2.91[a]	5.202[a]	7.905[a]	36.75[a]	28.66[b]
	IR-8839-39-1-6-4	3.68[a]	5.993[a]	9.01[a]	40.51[a]	30.64[a]
	IR-87759-7-1-2-3	3.22[a]	5.568[a]	8.623[a]	37.57[a]	29.20[ab]
	IR-88966-22-1-1-1	3.36[a]	5.715[a]	8.533[a]	40.01[a]	29.05[ab]
	IR-88839-3-1-2-2	2.82[a]	5.117[a]	7.577[a]	37.1[a]	30.84[a]
	IR-88869-2-2-2-2	3.1[a]	5.182[a]	7.746[a]	40.64[a]	29.45[ab]
	Sukhadhan-3	2.81[a]	5.29[a]	7.287[a]	32.57[a]	26.62[b]
F test		NS	NS	NS	NS	*
LSD (0.05)		0.6881	0.89	1.603	7.774	1.636
Weeding Practice	1: Weeded	3.993	6.9	9.93	39.81	30.43
	2: Non-weeded	2.321	4.11	6.43	35.94	28.74
F test		***	***	***	NS	***
LSD (0.05)		0.344	0.445	0.801	3.887	0.818
Interaction (Genotypes×Weeding practice)						
F test		NS	NS	NS	NS	NS
LSD (0.05)		0.973	1.259	2.267	10.994	2.314
CV%		18.50%	13.70%	16.60%	17.40%	4.70%
Grand mean		3.157	5.5	8.18%	37.88	29.59
SEM		0.583	0.755	1.359	6.593	1.387

*Mean in column followed by similar letters or absence of letters are not significantly different. NS = non-significance, * significance at 0.05 level of significance and ***significance at 0.001 level of significance*

Table 3: Effect of genotypes, weed management practices and their interaction on yield attributing traits of rice genotypes at Lamjung, Nepal, 2016

S.N.	Treatment Combination	Panicle Length (cm)	Effective Grains per Panicle	Non-Effective Grains per Panicle	Sterility %	Panicle Weight (g)
Genotypes						
	IR-87684-18-1-2-3	24.52b	89.83abc	34.95a	28.21ab	3.843a
	IR-83388-3-3-140-4	23.32bc	87.30bc	35.88a	28.35a	3.974a
	IR-8839-39-1-6-4	23.01c	100.80a	25.82b	21.84c	3.833a
	IR-87759-7-1-2-3	26.01a	98.89ab	35.61a	27.04abc	4.062a
	IR-88966-22-1-1-1	23.99bc	88.90abc	25.53b	20.94c	3.718a
	IR-88839-3-1-2-2	23.79bc	79.75c	35.17a	27.33abc	3.826a
	IR-88869-2-2-2-2	24.26bc	101.31a	30.10ab	24.90abc	4.127a
	Sukhadhan-3	23.02c	97.64ab	25.43b	21.81bc	4.208a
F test		***	**	**	*	NS
LSD (0.05)		1.243	11.06	7.08	5.712	0.674
Weeding Practice	1: Weeded	23.93	93.2	30.7	24.85	4.25
	2: Non-weeded	24.05	92.9	31.43	25.26	3.647
F test		NS	NS	NS	NS	***
LSD (0.05)		0.621	5.53	3.54	2.856	0.337
Interaction (Genotypes ×Weeding practice)						
F test		NS	NS	NS	NS	NS
LSD (0.05)		1.758	15.63	10.013	8.077	0.953
CV%		4.40%	10.10%	19.30%	19.30%	14.50%
Grand mean		23.99	93.1	31.06	25.05	3.949
SEM		1.054	9.38	6.005	4.844	0.572

*Mean in column followed by similar letters or absence of letters are not significantly different. NS = non-significance, * significance at 0.05 level of significance, ** significance at 0.01 level of significance and ***significance at 0.001 level of significance*

means that a single unit increase in test grain weight increased grain yield by 21.71%.

Likewise, similar kind of significant and positive correlation were observed for plant height and panicle weight to be y = 0.13x-10.085, R^2 = 0.2567 and y = 0.8946x-0.3758, R^2 = 0.2515 respectively (Figure 2 and 3). It means when plant height and panicle weight will increase or decrease by one unit then grain yield of rice will also increase or decrease by 0.13 and 0.8946 times respectively. Likewise, co-efficient of determination showed single unit increasement in plant height and panicle weight caused 25.67 and 25.15% increasement in grain yield respectively. Previous research findings also supports the following results (Rajeshwari and Nadarajan 2004; Xu et al. 2015).

Whereas, Regression analysis done for sterility percentage showed negative but non-significant result in grain yield with the equation of y = -0.0057x + 3.3001 and

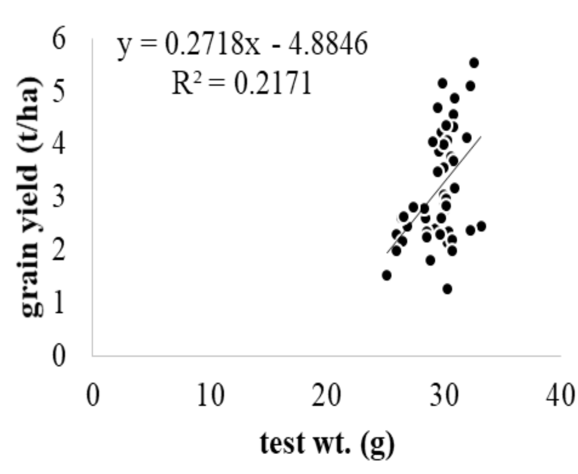

Figure 1: Scattered plot of grain yield vs test wt

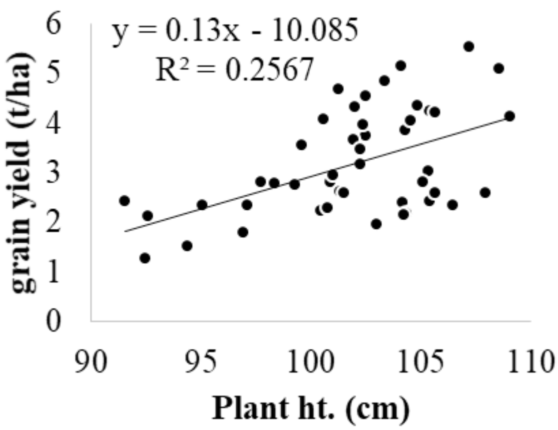

Figure 2: Scattered plot of grain Yield vs plant ht

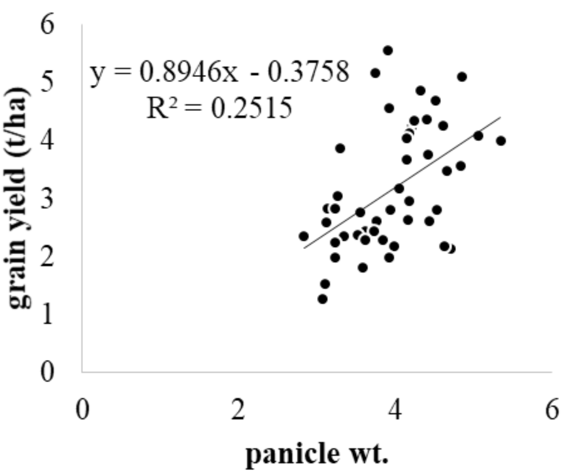

Figure 3: Scattered plot of grain yield vs panicle wt

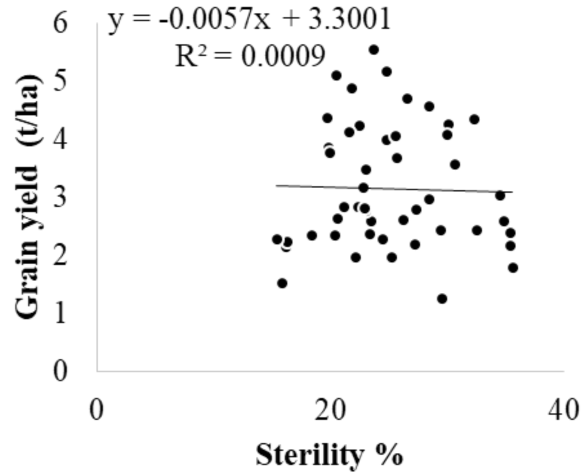

Figure 4: Scattered plot of rain Yield vs Sterility %

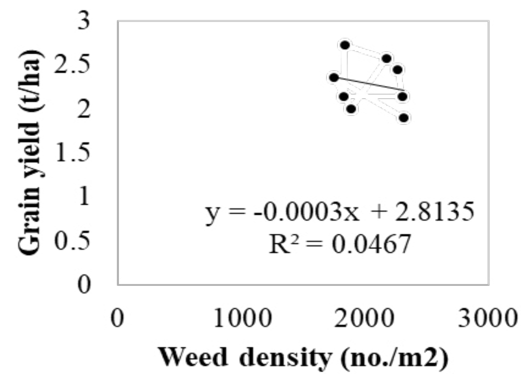

Figure 5: Scattered plot of grain yield vs weed density

$R^2 = 0.0009$ (Figure 4). It showed that a unit increase in sterility percentage has decreased grain yield of rice by 0.0057 times and 0.09%.

Regression analysis done for weed density showed negative but non-significant result in grain yield with the equation of y = -0.0003 + 2.8135 and $R^2 = 0.0467$ (Figure 5). It showed that a unit increase in weed density has decreased grain yield of rice by 0.0003 times and4.67%.

3.3 Weed density characteristics

3.3.1 Frequency distribution of weed species

Frequency distribution of weed showed to be higher in *Rotala indica* (18%), followed by *Eriocaulon cinereum* (12.20%), *Ammania baccifera* (10.37%), *Scripus mucronatus* (9.45%), *Fimbristylis miliacea* (8.54%), *Ludwigia octovalvis* (8.38%), *Cyperus difformis* (5.18%), *Ageratum species* (4.27%), *Monochoria vaginalis* (3.05%), *Lindernia anguistifolia* (2.90%), *Cynodon dactylon* (2.74%), *Evolvulus nummularis* (2.74%) and other weed species in lower proportions (Table 4). Highest frequency proportion of *Rotala indica* in rice field could have occurred due to the marshy, submerged condition and suitable climatic condition in rice field that provided suitable habitat for it in research site as described by (Zhuang 2011). Weed species of Cyperaceae family (5), Gramineae (5), Asteraceae (3), Lytharaceae (2), Pontederiaceae (1), Tiliaceae (1), Onagraceae (1), Apiaceae (1), Lauraceae (1) and Convolvulaceae (1) were recorded.

Table 4. Frequency distribution of different weed species at experimental rice field of Sundarbazar, Lamjung in 2016

S.N.	Scientific name	English name	Nepali name	Family	Classification	Distribution Frequency (%)
1	*Rotal indica*	Indian tooth cup	Belauti jhar	Lythraceae	Perennial, Broad leaf	18
2	*Eriocaulon cinereum*	Ashy pipe worts	Buche Jhar	Eriocaulaceae	Annual, Grass	12.2
3	*Ammania baccifera*	Monarch red stem	Ambar	Lythraceae	Annual, Broad leaf	10.37
4	*Cyperus difformis*	Small flower umbrella plant	Mothe jhar	Cyperaceae	Annual, Sedge	5.18
5	*Fimbristylis miliacea*	Grass like fimbry	Jwane jhar	Cyperaceae	Annual, Sedge	8.54
6	*Fimbristylis schenoides*	Ditch fimbry	Mothe jhar	Cyperaceae	Annual, Sedge	7.93
7	*Monochoria vaginalis*	Oval leaf pond weed	Jaluki jhar	Pontederiaceae	Annual/perennial, Broad leaf	3.05
8	*Scirpus mucronatus*	Rice field bulrush	Mothe jhar	Cyperaceae	Perrenial, Sedge	9.45
9	*Cyperus iria*	Rice flat sedge	Thulo mothe jhar	Cyperaceae	Annual, Sedge	1.22
10	*Cynodon dactylon*	Bermuda grass	Dubo jhar	Gramineae	Annual, Grass	2.74
11	*Truimfetta rhomboides*	Chinese burr	Dalle kuro	Tiliaceae	Annual broad leaf	0.42
12	*Ludwigia octovalvis*	Mexican primerose willow	Lwang jhar	Onagraceae	Annual, Broad leaf	8.38
13	*Digitaria ciliaris*	Tropical finger grass	ChitreBasno	Gramineae	Annual, Grass	0.42
14	*Ageratum conyzoides/ haustonianum*	White weed/ Blue weed	Seto gandhe/Nilo gandhe	Asteraceae	Annual, Broad leaf	4.27
15	*Centella asiatica*	Indian pennywort	Ghod tapre	Apiaceae	Perrenial, Broad leaf	0.27
16	*Digitaria abyssinicia*	African couch grass	Banso jhar	Gramineae	Annual, Broad leaf	0.27
17	*Lindernia anguistifolia*	Oriental spice bush	Oriental spicebush	Lauraceae	Annual, Broad leaf	2.9

3.3.2 Weed biomass and weed density in different time interval

Dry weight and fresh weight were taken for observation in 40DAT, 50DAT, 60DAT, 70 DAT and 80 DAT (Figure 6). The maximum fresh weight was found to be 885 gm^{-2} in 40DAT which may be due to presence of Critical period of Weed Control (CPWC) for rice crop. In main season, CPWC ranges from 7-53 days after seeding (Anwar et al. 2012). Likewise, direct seeded rice to be kept weed free from 2-71 days after seeding in flooded condition to get at least 95% of weed free yield (Juraimi et al. 2009). It may be so because, weed seed germinates 3-5 days earlier than rice seed due to faster growth rate and infest easily (Nyarko and Datta 1991).

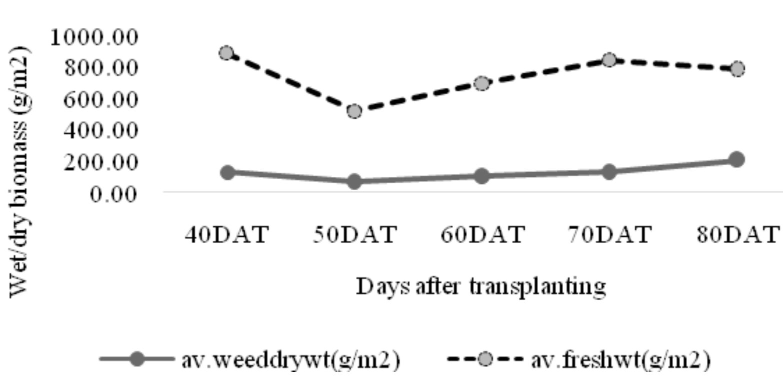

Figure 6: Weed biomass in different time interval

Likewise, Density of *Rotala indica* found to be significantly higher than other species. The density of *Rotala indica* found to be 850, 1366.67, 1100 1145.83 plants m^{-2} in 40 DAT, 50 DAT, 60 DAT, 70 DAT and 80 DAT were recorded respectively (Table 5). Similarly, *Rotala indica* was followed *by Eriocaulon cinereum* with density of 295.83, 329.17, 191.67, 208.33 and 204.17 plants m^{-2} in 40 DAT, 50 DAT, 60 DAT, 70 DAT and 80 DAT respectively. Whereas, other weed species showed significantly lower plant density.

Reduction of biomass in 50DAT to be 517.5 gm^{-2} and increment in latter days as well as fluctuation in weed density may be due to fluctuation in climatic parameters like light intensity and temperature (Chen et al. 2007), Photoperiod (Huang et al. 2000) and rainfall or water level that can affect the growth and development of weeds (Sen et al. 2002) and effect in weed seedling growth & development (Kim et al. 2016).

3.3.3 Average weed density on different rice genotypes

The significantly lowest average weed density was seen in 88869-2-2-2-2 followed by IR-8839-39-1-6-4 and 87759-7-1-2-3 to be 1746.67, 1826.79 and 1833.33 plants m^{-2} respectively being statistically at par among each other (Figure 7). Whereas, the significantly highest weed density was found in Sukhadhan-3 followed by IR-83388-3-3-140-4, IR-87684-18-1-2-3 and IR-88966-22-1-1-1 to be 2313.33, 2300.00, 2259.87 and 2173.33 plants m^{-2} respectively being statistically at par among each other. Lower weed density showed higher weed suppressing ability of 88869-2-2-2-2 and 8839-39-1-6-4 rice genotypes. Some rice varieties have competitive ability to suppress weed density (Sunyob et al. 2015). Whereas, regression analysis done for weed density showed negative but non-significant result in grain yield with the equation of $y = 0.0003x + 2.8135$ and $R^2 = 0.0467$. It showed a unit increase in weed density decreased grain yield by 0.0003 times and 4.67%.

Table 5: Density of different weed species during different time interval during rice crop period at Sunadarbazar, Lamjng in 2016

S.N	Weed species	Density of weed species in different time interval (population no./m2)				
		40DAT	50DAT	60DAT	70 DAT	80 DAT
1	*Rotal indica*	850	1366.67	991.67	1100	1145.83
2	*Eriocaulon cinereum*	295.83	329.17	191.67	208.33	204.17
3	*Ammania baccifera*	112.5	116.67	75	95.83	75
4	*Cyperus difformis*	158.33	41.67	16.67	0	29.17
5	*Fimbristylis miliacea*	191.67	100	158.33	137.5	116.67
6	*Fimbristylis schenoides*	175	83.33	58.33	83.33	58.33
7	*Monochoria vaginalis*	158.33	33.33	12.5	4.17	12.5
8	*Scirpus mucronatus*	104.17	91.67	83.33	66.67	112.5
9	*Cyperus iria*	29.17	4.17	4.17	8.33	4.17
10	*Cynodon dactylon*	45.83	16.67	8.33	12.5	50
11	*Truimfetta rhomboides*	8.33	0	0	0	0
12	*Ludwigia octovalvis*	150	79.17	87.5	62.5	87.5
13	*Digitaria ciliaris*	4.17	8.33	0	0	0
14	*Ageratum conyzoides/ haustonianum*	50	25	8.33	62.5	50
15	*Centella asiatica*	4.17	0	0	0	0
16	*Digitaria abyssinicia*	4.17	0	0	0	0
17	*Lindernia anguistifolia*	16.67	12.5	54.17	20.83	20.83
18	*Evolvulus nummularis*	0	12.5	8.33	20.83	54.17
19	*Galinsoga parviflora*	0	0	0	16.67	16.67
20	*Eclipta prostata*	0	0	0	20.83	0
21	*Digitaria eriantha*	0	20.83	0	0	0
22	*Paspalum distichum*	0	70.83	0	0	0

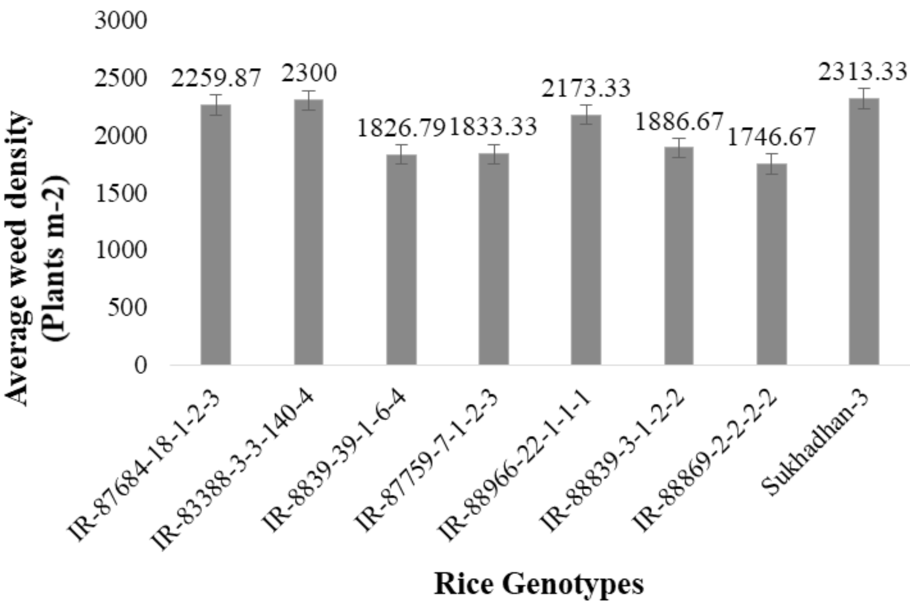

Figure 7: Average weed density of different Rice Genotypes field of Sundarbazar, Lamjung in 2016

4 Conclusion

From this research, all tested rice genotypes found to be showing similar yield capacity. Dominant rice weed of Sundarbazar found to be *Rotala indica* (Belauti Jhar). Infestation of weeds have significantly reduced rice grain yield. IR-8839-39-1-6-4 and Sukhadhan-3 are early maturing genotypes. Further detailed study are required to know the most efficient method of weeding practice that could mitigate the weed problem in rice.

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