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GROWTH AND YIELD OF RICE AS INFLUENCED BY IRRIGATION REGIMES AND WEED MANAGEMENT PRACTICES UNDER SRI METHOD OF RICE CULTIVATION

Ashaq Hussain, Intikhab Aalum Jehangir*, Aabid Hussain Lone, Nazeer A. Teeli and Tasneem Mubarak

Mountain Research Centre for Field Crops, SKAUST-Kashmir, Khudwani,192102, J&K, India

*Corresponding author Email: intikhabaalum@gmail.com

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ABSTRACT

Any agronomic management practices that enhance the rice productivity coupled with efficient utilization of the critical inputs, offers a viable option for its sustainability. In this context a two-year field study was initiated at Mountain Research center for field crops Khudwani, SKUAST-Kashmir during two consecutives kharif seasons of 2017 and 2018 to study the effect of irrigation regimes and weed management practices on the productivity of rice. Intermittent irrigation reflected an increase in the number of panicles (8%) and grain yield by 4.75 % over conventional flooding. Among the weed management practices pre-emergence application of butachlor @1.5 kg ha^{-1} fb penoxsulam @ 22.5 g ha^{-1} 20 DAT led to enhancement in yield attributes, yield and nutrient uptake, while minimizing the values for weed density (10 plants/m^2) and dry matter (20.4 g/m^2) compared to weed density of 98 plants/m^2 and the corresponding weed dry matter of 220 g/m^2 in weedy check. The weedy check plots registered lower values for uptake of N, P, K by, 54%, 53% and 52%, respectively compared to herbicide treatment of butachlor @1.5 kg ha^{-1} (3 DAT) fb penoxsulam @ 22.5 g ha^{-1}. The results suggest that the improvement in the productivity of rice crop can be realized to the tone of 4.5% by following the intermittent irrigation and 56 % by resorting to application of butachlor @1.5 kg ha^{-1} (3 DAT) fb penoxsulam @ 22.5 g ha^{-1} 20 DAT.

***Keyword*:** Irrigation Regimes, Weed Management, SRI Method, Rice Cultivation.

Introduction

Rice is the most important cereal crop of India as it is the staple food for majority of the population. Total production of rice during 2022-23 is estimated at 135.54 million tonnes from an area 47 million ha. The demand of rice India is projected at 150 million tonnes by 2030. Rice is also one of important food crops of UT of Jammu and Kashmir with a production of 58.16 lakh tonnes and an area of 2.67 lakh ha during 2020-21. Rice is a water guzzler crop and it takes 3000 - 5000 L of water to produce a kg of rice. The problem of water shortage is exacerbated by increasing water demand from domestic and industrial sectors and reduced rainfall as the fallout of climate change (Tong *et al.,* 2022). Increased frequency of droughts and extreme weather events is likely to affect rice and other crops in future (Zhao *et al*., 2022). Efforts are being put in to develop and popularize technologies that result in a significant water saving such as system of rice intensification (SRI), aerobic and direct seeded rice. Yield losses in rice have been estimated at 10-100 % depending on the establishment method, weed competition and floristic composition, crop variety and many other agroclimatic factors (Roa, 2014). Maintenance of flooded conditions further smothers the forthcoming weeds. However, in the latter phases of vegetative growth aquatic weeds predominate. Alternate wetting and drying as recommended under SRI method stimulate germination of all kinds of weeds commonly associated with rice. Under such situations it often becomes difficult and economically unviable to keep weeds below economic threshold level through manual or mechanical means as recommended under SRI. While taking advantage of the other principles and practices of SRI, weeds can be managed through the application of herbicides. Therefore, it is imperative to look for alternative strategies particularly the cost-effective herbicides under SRI management. Butachlor (1.5 kg/ ha) is the most commonly used herbicide in rice in Kashmir. Penoxsulam @ 22.5 g/ha, bispyribac @ 25 g/ha, pyrazosulfuron @ 30 g/ha are some the relatively new herbicides being evaluated in transplanted rice. Penoxsulam @ 22.5 g/ha is used both as a pre-emergence and early post emergence herbicide in rice. Therefore, the experiment titled **"**Growth and yield of rice as influenced by weed management and irrigation practices under SRI method of rice cultivation" was conducted to assess the response of rice and associated weed flora to irrigation regimes and weed management practices.

Materials and Methods

The field experiment was conducted at Mountain Research Centre for Field Crops (MRCFC), SKUAST-Kashmir, Khudwani. The soil of the experimental plot was silty clay loam in texture, low in soil available N (214.5 kg ha^{-1}), medium in P (12.3 kg ha^{-1}) and K (234.0 kg ha^{-1}). Precipitation received during first and second year of experimentation was 889 mm and 402 mm, respectively. Treatments comprising of two irrigation regimes and eight weed management practices were laid out in split plot design with three replications. Irrigation regimes included flooding (I_1) and irrigation three days after the disappearance of ponded water (DAPW) (1_2), were allotted to the main plots and weed management practices comprised of penoxsulam @ 22.5 g ha^{-1} 3DAT (W_1); bispyribac sodium @ 25 g ha^{-1} 20 DAT (W_2) ; pyrazosulfuron @ 30 g ha^{-1} 3DAT (W_3); butachlor @1.5 kg ha^{-1} (3 DAT) fb penoxsulam @ 22.5 g ha^{-1} 20 DAT (W_4); butachlor @1.5 kg ha^{-1} 3 DAS (W_5); Mechanical weeding (Cono-weeded) 15 and 35 DAT (W_6); Weedy check (W_7) and wee free (W_8) were allotted to the subplots. Sixteen-day old single seedling per hill were transplanted at a spacing 25 × 25 cm. Fertilizer dose of 120 kg N, 60 kg P_2O_5 and 30 kg K_2O in the form of Urea, DAP and MOP, respectively were applied along with 10t FYM ha^{-1} as the same was found superior in the earlier experiments conducted on SRI. Other field operations were performed as per recommended package.

Weed indices were calculated using the following formulae:

The weed index (WI) and weed control efficiency (WCE) were calculated from the mean data over two years by using following formulae.

Weed Control Efficiency (WCE) = DWC – DWT/DWC x 100 DWC where, DWC and DWT are dry weight of weed from unwedded and weeded plots, respectively.

Weed Index (W I) = a-b/ a x 100 where 'a' and 'b' are grain yields from the best treatments and treatment for which WI is to be computed.

The data were statistically analyzed by Gomez and Gomez (1978).

Results and Discussion

Effect on crop growth parameters

Plant height an important growth character remained statistically unaffected among the two Irrigation regimes, though numerically higher values were registered with I2. Similar trend was apparent in respect of SPAD reading and dry matter accumulation (kg m^{-2}) (Table 1). On the contrary irrigation regime (I_2) depicted significant effect on leaf area index, with the superiority of 2.1 over continuous flooding (I_1). This improvement in LAI under intermittent irrigation regime can be attributed sufficient soil aeration, which might have promoted root and tiller production. Similar results have been reported by Thyagarajan and Selvaraju (2001), Balasubramanian and Krishnarajan (2001). Among the weed management practices plant height varied between 110 cm- 126 cm, with significantly tallest plants (126 cm) registered in weed free treatment closely followed by pre-emergence application of butachlor (1.5 kg ha^{-1}) fb penoxsulam @ 22.5 g ha^{-1} and penxosulam @ 22.5 g/ha alone and these were at par with weed free check. Weed management practices had similar impact on other growth parameters. Combined application butachlor (1.5 kg ha^{-1}) fb pexoxulam @ 22.5 g ha^{-1} was the second best in terms of LAI and was at par with weedy check. The percentage increase in LAI under W_8 and W_4 over W_7 was 46.2 and 38.3 %, respectively. Sequential application of pre and post-emergence herbicides had a favorable effect on crop growth and yield parameters (Mohapatra *et al*., 2016). Due to severe competition for both above and below ground resources on account of higher weed infestation weedy check treatments depicted significant reduction in the SPAD value, in contrast weed free treatment recorded highest SPAD values but was found statistically at par with other herbicidal treatments and mechanical weed control. (Table 1). Dry matter accumulation followed the trend of W_8>W_4>W_2=W_6> W_3 = W_5 > W_1 > W_7 > W_4. Higher dry matter accumulation registered with W_8 and W_4 can be attributed to lack of competition for resources on account weed free environment.

Effect of yield attributes and yield

The favorable effect of intermittent irrigation was recorded in no. of tillers/m^2. On an average I_2 recorded significantly higher number of tillers /m^2 (419) with an increase of 8% over I_1. Among the weed management practices apart from weed free, butachlor (1.5 kg ha^{-1}) fb pexoxulam @ 22.5 g ha^{-1} produced statistically similar values for no. of tillers/m^2. Additionally, an increment of 37.4% and 32.0 % in tiller no/m^2 was registered in W_8 and W_4 over W_7, respectively. All the other herbicides produced significantly lower no of tillers m^{-2}. Irrigation regimes significantly affected panicles/m^2 (Table 8.3). Intermittent drainage stimulated tillering and the same was manifested in higher no. of panicles m^{-2} in I_2. On an average there was 5.5% increase in no of panicles m^{-2} over I_1. Improved growth, yield attributes and yield have been reported by many workers under alternate wetting and drying method of irrigation in rice (Djaman *et al*., 2018). The weed management practices also affected the no. of panicles m^{-2}significantly. Lowest no of panicles m^{-2} was recorded in weedy check. Among the weed management practices butachlor (1.5 kg ha^{-1}) fb penoxulam @ 22.5 g ha^{-1} (T_4) was noted as the second best in terms of panicles m-^{2} after weedy free check with the superiority of 31% over weedy check. No. of grains panicle^{-1} was significantly affected by irrigation regimes. There was about 9% increase in no. of grains panicle^{-1} in I_2 over I_1. Positive impact of AWD practice on yield attributes and yield of rice has been reported by Rejesus *et al.* (2011); Lampayan *et al.* (2015). With regard to no. of grains panicle^{-1} weed free and butachlor (1.5 kg ha^{-1}) fb pexoxulam @ 22.5 g ha^{-1} were statistically at par. There was gain of 28 % and 26% in no. of grains/panicle in weed free treatment and treatment resorted application of butachlor (1.5 kg ha^{-1}) fb pexoxulam @ 22.5 g ha^{-1}, respectively.1000 seed weight remained unaffected by both irrigation regimes and weed management. Our results align with the findings of Babar and Velayutham (2012); Mohapatra *et al.* (2016), who reported increment in the rice seed yield on account of sequential application of pre- and post-emergence herbicides.

The grain yield, straw yield and dry matter accumulation was significantly affected by irrigation levels and weed management practices (Table 2). Our findings reflected an increase of about 4.75% and 3.5% in grain and straw yield, respectively in I_2 over I_1. Yang and Zhang (2010) reported an increase in rice yield under AWD due to the increase of the proportion of productive tillers, reduction in the angle of the topmost leaves allowing more light penetration into the canopy, and change in shoot and root activity. Under weed management practices seed yield varied from 4. 25 t ha^{-1} in weedy check to 6.68 t ha^{-1} in weed free treatment. In general, all the herbicide treatments though managed to register significantly higher seed yield over weedy check, but remained at par with each other. Butachlor (1.5 kg ha^{-1}) fb penoxsulam @ 22.5 g ha^{-1} (T_4), though remaining at par with weed free treatment registered significantly higher seed yield of 6.65 t ha^{-1} with the superiority of about 68.50% over weedy check for the data averaged over 2017 and 2018. Sequential application of butachlor (1.5 kg ha^{-1}) fb penoxsulam @ 22.5 g ha^{-1} provided a season long weed control and therefore was at par weed free check. Weed free followed by butachlor (1.5 kg ha^{-1}) fb penoxsulam @ 22.5 g ha^{-1} recorded significantly higher straw yield with the superiority of 55 and 52.5%, respectively over weedy check. Several workers have reported a significant increase in grain yield under sequential application herbicides in rice (Babar and Velayutham 2012; Mohapatra *et al.* 2016).

Effect on weed flora

The most common weeds in rice in Kashmir are *Echinocloa crusgali* L., *Echinocloa colona* L., *Cyperus iria* L., *Cyperus difformis* L., *Marsilia quadrifolia* L., *Potamogeton distinctus.,* A. Benn., *Ammania baccifera* L. and *Monochoria vaginalis*. Weeds dry matter recorded at 35 DAT was significantly affected by irrigation regimes. Intermittent irrigation recorded significantly higher weed dry matter than continuous flooding. On an average there was increase of 14.5% increase in dry matter due to irrigation 3 days after DAPW (I_2). Exposure of soil surface provides better aeration that favour weed seeds to germinate in case of application of alternate wetting and drying (Patel, 2000; Murugan *et al.,* 2019; Jehangir *et al*., 2021). Among the weed management practices weedy check had the highest weed dry matter accumulation. Among the herbicidal treatments sequential application butachlor (1.5 kg ha^{-1}) fb pexoxulam @ 22.5 g ha^{-1} (T_4) recorded the lowest values for weed dry matter accumulation. On an average T_4 treatment resulted in a 90.7% reduction in dry matter accumulation of weeds over weedy check. The other herbicidal treatments were at par with each other. Likewise, significantly higher number of weeds/m^2 were noted under I_1 compared to I_2. There was increase of 14.3% in weed density/m^2 in I_2 over I_1. Similarly weed management practices impacted the weed population (Number m^{-2}).

Maximum number of weeds (98 m^{-2}) were recorded in weedy check and the lowest were recorded in the treatment resorted to sequential application of butachlor (1.5 kg ha^{-1}) fb penoxulam @ 22.5 g ha^{-1} (T_4) Additionally a discernible amount of 90% reduction in weed population was reflected by T_4 over weedy check. Furthermore, sequential application of herbicides recorded highest weed control efficiency (90.5%) and weed control index (89.0%). These results consistent with the findings of Jehangir *et al.* (2024), who reported better weed control while resorting to sequential application of herbicides. The reduction in the yield over weed free plot as represented by weed index was just 3.3%, the lowest among all the herbicidal treatments. Our results are in conformity with the results of Walia and Walia (2012).

Effect on nutrient uptake by the crop

In general, higher uptake of nutrients was recorded under I_2 over I_1, though the values remained non-significant during 2017 and 2018 for N and K uptake, respectively (Table 4). On an average there was an increase in uptake under intermittent irrigation (I_2) to the tone of 4%, for N and K and 5% for P. Under weed management practices lowest uptake of nutrients was recorded in weedy check for each nutrient. Our findings reflected an increase in uptake of nutrients (N, P) over weedy check to the tone of 63% in weed free and 54.3 and 53% in favor of butachlor (1.5 kg ha^{-1}) fb penoxsulam @ 22.5 g ha^{-1} over weedy check, respectively. Weeds are very efficient in nutrient removal from the soil. The lowest uptake of 89.2 kg/ha of K was recorded in weeds check. The increase in K uptake in weed free and butachlor (1.5 kg ha^{-1}) fb penoxsulam @ 22.5 g ha^{-1} was of the order of 60.8 and 52.8% respectively. This lower uptake of nutrients in weedy check treatments exhibit the superiority of weeds as an efficient nutrient scavengers compared to crop.

Relationship between grain yield, crop growth and weed growth parameters

There was a significant and positive relationship between grain yield and leaf area index (R^2=0.95), SPAD (R^2=0.87), dry matter accumulation (R^2=0.97), panicles m^{-2} (R^2=0.95), 1000 grain weight (R^2=0.94) (Fig. 1). Higher growth attributes and partitioning of dry matter into the grain yield resulted higher growth under superior treatments. Yield on the other hand, there was a negative correlation between grain yield weed density (R^2=0.95) and weed dry matter m^{-2} (R^2=0.96). Weeds compete with crop plants for resources and result on suppression of crop growth and yield and therefore demonstrated a negative correlation.

Conclusion

From this study it is concluded that there was an increase of about 4.75% in grain yield in I_2 over I_1. Weed free and butachlor (1.5 kg ha^{-1}) fb penoxsulam @ 22.5 g ha^{-1} (T_4) resulted in yield increase about 58% over weedy check. Overall I_2 resulted in a water saving of 35%.

Table 1 : Effect of irrigation regimes and weed management practices on plant growth parameters and dry matter accumulation

	Plant height (cm)	Leaf area index	Tillers m^{-2}*	SPAD readings	Dry matter accumulation (Kgm^{-2})
Irrigation levels					
I_1	120.2	4.26	396	37.52	1.22
I_2	122.0	4.35	419	37.85	1.28
C.D $_{(p\leq 0.05)}$	NS	0.30	17.15	NS	NS
SEm±	1.01	0.07	4.28	0.44	0.01
Weed management practices					
W_1	122.6	4.46	415	38.0	1.28
W_2	121.5	4.45	411	37.4	1.30
W_3	121.1	4.27	400	38.1	1.27
W_4	125.0	4.58	439	38.3	1.35
W_5	121.3	4.26	402	37.6	1.27
W_6	121.0	4.21	414	38.6	1.30
W_7	110.6	3.31	331	34.5	0.87
W_8	126.0	4.84	455	39.1	1.41
C.D $_{(p\leq 0.05)}$	6.47	0.30	19.41	2.21	0.09
SEm±	2.16	0.10	6.47	0.72	0.03

*At maximum tillering stage

Table 2: Effect of irrigation regimes and weed management practices on yield attributes and yield of rice under SRI method (Pooled over two years)

	Panicles m^{-2}	No. of grains $panicle^{-1}$	1000 grain weight (g)	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)
Irrigation regimes					
I_1	342	78.5	25.1	6.04	7.62
I_2	361	85.7	25.6	6.34	7.89
C.D $_{(p\leq 0.05)}$	15.14	4.47	NS	0.21	0.31
SEm±	3.71	1.09	0.19	0.05	0.07
Weed management practices					
W_1	369	82.6	25.6	6.55	7.81
W_2	358	83.9	25.5	6.47	8.18
W_3	346	82.5	25.2	6.23	7.92
W_4	370	88.6	25.5	6.65	8.34
W_5	353	80.3	25.7	6.29	7.70
W_6	354	79.1	25.0	6.20	8.05
W_7	282	70.0	24.4	4.25	5.49
W_8	378	89.5	25.4	6.88	8.55
SEm±	5.27	1.80	0.42	0.15	0.19
C.D $_{(p\leq 0.05)}$	16.23	5.44	NS	0.45	0.60

Table 3: Effect of irrigation regimes and weed management practices weed dry-matter and weed density and weed control indices.

Treatments	Weed dry matter ($g\ m^{-2}$) *			Weed density (No. m^{-2})			Weed control efficiency (%)		Weed index
	2017	2018	Average	2017	2018	Average	2017	2018	
Irrigation Levels									
I_1	63.5 (7.2)	59.4(6.95)	61.4 (7.1)	29.0 (4.9)	27.2(4.8)	28.1 (4.9)	-	-	
I_2	72.5 (7.7)	68.4 (7.45)	70.3 (7.6)	33.1 (5.3)	30.7(5.1)	31.9 (5.2)	-	-	
C.D $_{(p\leq 0.05)}$	3.69	3.42	3.56	3.09	2.82	2.96			
SEm±	0.90	0.83	0.87	0.77	0.68	0.72			
Weed management practices									
W_1	49.5 (7.1)	45.7 (6.8)	47.6 (6.9)	23.6 (4.9)	22.1(4.8)	22.90(4.9)	78.055	76.7	4.80
W_2	50.2 (7.1)	46.7 (6.9)	48.4 (7.01)	23.2 (4.9)	21.9(4.8)	22.55(4.8)	77.66	77.0	5.96
W_3	61.4 (7.9)	57.9 (7.6)	59.6 (7.8)	26.9 (5.3)	25.4(5.1)	26.15(5.2)	72.49	73.3	9.45
W_4	21.1 (4.7)	19.8 (4.5)	20.4(4.62)	10.8 (3.4)	10.0(3.3)	10.4(3.4)	90.57	89.4	3.34
W_5	78.7 (8.9)	74.3 (8.7)	76.5 (8.8)	33.90(5.9)	31.5(5.7)	32.73(5.8)	64.72	66.6	8.58
W_6	59.0 (7.7)	55.6 (7.5)	57.3(7.6)	28.2 (5.4)	26.4(5.2)	27.35(5.3)	73.575	72.1	9.88
W_7	223.9(14.9)	209.8(14.5)	216.9(14.7)	101.7(10.1)	94.3(9.7)	98.01(9.9)	0.0	0.0	38.23
W_8	0.0 (1.0)	0.0 (1.00)	0.0(1.0)	0.0 (1.0)	0.0(1.0)	0.0(1.0)	100	100.0	0.00
SEm±	2.38	2.15	2.26	1.12	1.04	1.08			
C.D(p≤ .05)	7.19	6.75	6.97	3.48	3.23	3.36			

*Values in parentheses are transformed to $\sqrt{x+0.5}$

Table 4: Effect of irrigation regimes and weed management practices N, P and K uptake ($Kg\ ha^{-1}$) in rice under SRI method.

Treatments	N			P			K		
	2017	2018	Average	2017	2018	Average	2017	2018	Average
Irrigation Levels									
I_1	112.7	116.2	114.5	27.0	25.8	26.4	129.7	120.7	125.2
I_2	117.3	120.9	119.1	28.1	27.3	27.7	134.2	126.4	130.3
C.D $_{(p\leq 0.05)}$	NS	4.21	4.21	1.05	NS	1.05	4.11	5.43	4.77
SEm±	0.83	1.04	0.99	0.18	0.42	0.26	1.03	1.36	1.19
Weed management practices									
W_1	118.5	123.3	120.9	28.8	28.3	28.6	134.6	126.5	130.6
W_2	118.9	122.3	120.6	27.9	26.7	27.3	138.9	131.2	135.0
W_3	116.4	117.7	117.1	28.1	27.1	27.6	131.4	123.7	127.5
W_4	122.7	127.6	125.2	29.3	28.1	28.7	139.9	132.6	136.3
W_5	117.2	120.0	118.6	28.3	27.1	27.7	134.1	120.9	127.5
W_6	117.0	120.7	118.8	27.9	26.6	27.3	136.4	128.4	132.4
W_7	80.3	81.9	81.1	19.3	18.2	18.7	92.6	85.9	89.2
W_8	129.0	135.1	132.0	30.9	30.1	30.5	147.5	139.5	143.5
C.D $_{(p\leq 0.05)}$	6.74	5.36	6.05	NS	1.85	1.85	6.75	5.96	6.36
SEm±	2.91	3.21	3.03	0.71	2.85	2.72	4.72	5.01	4.85

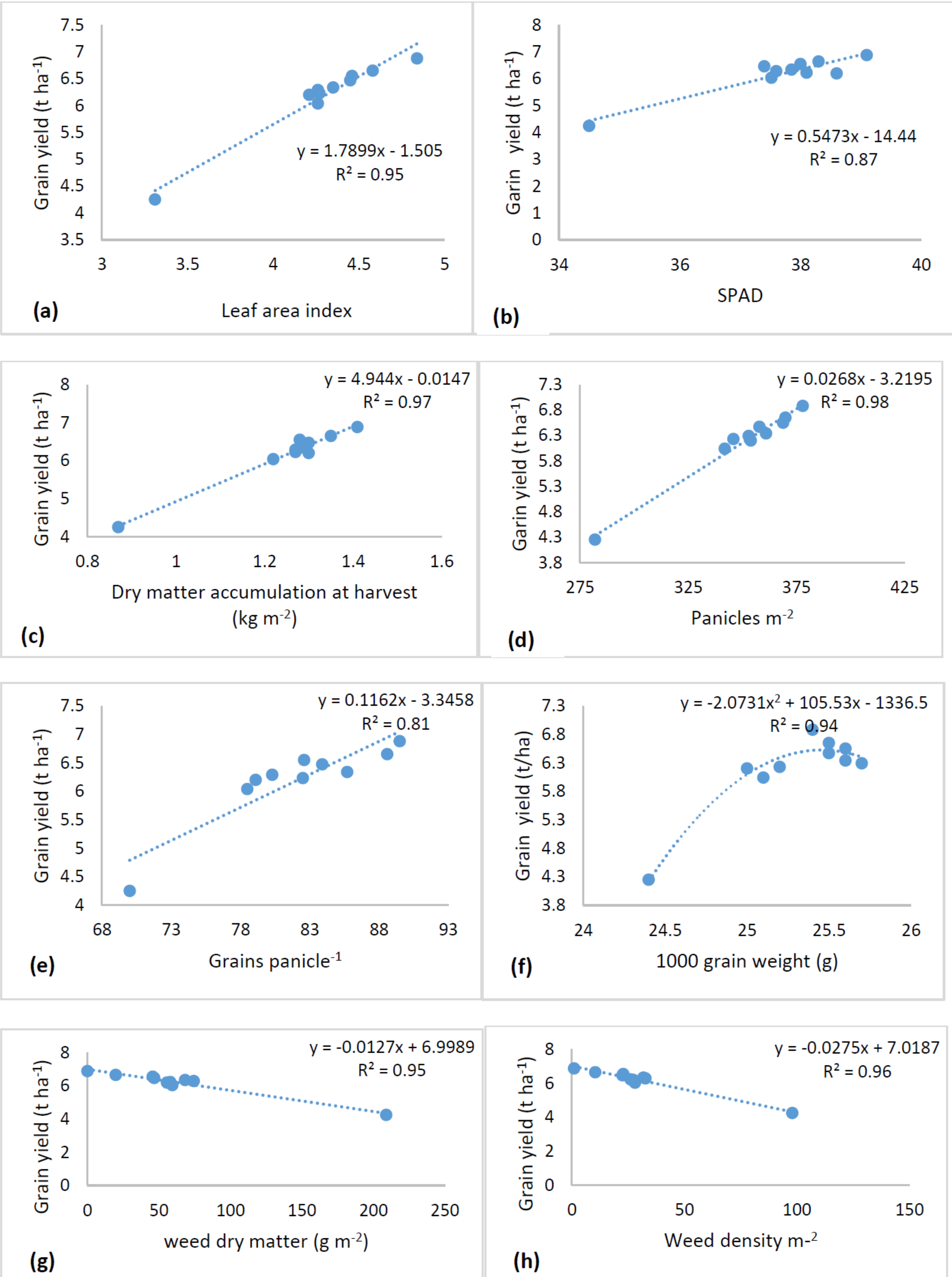

Fig. 1 : Relationship between grain yield leaf area index (a), grain yield and SPAD (b), grain yield and dry matter (c), grain yield and panicles/m^2 (d), grain yield and grains/panicle (e), grain yield and 1000 grain weight (f), grain yield and weed dry matter/m^2 (g), grain yield and weed density (m^2)

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