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Uptake of Zn and Fe by direct seeded rice as influenced by weed control methods, major and micronutrients

Kaviti Vijayalakshmi, APK Reddy, AV Ramana, P Sudhakar, TNVKV Prasad and B Ravindra Reddy

Abstract
A field experiment on dry direct sown rice was conducted for two consecutive *kharif* seasons during 2018 and 2019 at Agricultural College Farm, Naira, Srikakulam of North-Coastal zone of A.P. Significant differences were noticed in growth, yield and uptake of Zn and Fe by grain and straw due to weed control methods, nutrient management practices and application of micronutrients. Significant reduction in the total weed density and increased the crop growth parameters *viz*., plant height and SPAD meter readings and yield parameters *viz*., productive tillers m^{-2}, grain and straw yield and uptake of Zn and Fe by grain and straw at harvest due to sequential application of pyrazosulfuron ethyl *fb*.florpyrauxifen-benzyl which was however, found parity with bispyribac sodium *fb*. 2,4-D amine salt + fenoxyprop-ethyl with safener. Weedy check registered the lowest values for all these parameters. Among nutrient management practices, application of 100% RDF produced taller plants, higher SPAD meter values and more number of productive tillers m^{-2}, higher grain and straw yields. With regard to application of micronutrients, basal application of $ZnSO_4$ @ 50 kg ha^{-1} exhibited significantly superior performance over other two treatments in this regard. Significantly higher uptake values for Zn by grain and straw were noticed with basal application of $ZnSO_4$ @ 50 kg ha^{-1} whereas, foliar application of $ZnSO_4$ @ 0.2% and $FeSO_4$ @ 0.5% each at 20 and 40 DAS registered significantly higher uptake of Fe by grain and straw.

Keywords: Uptake of Zn and Fe experiment on dry direct sown rice *fb*.florpyrauxifen-benzyl DAS registered significantly higher

Introduction
Advancement of research in herbicide technology opened a new vista that has led to identification of several low dose high efficiency broad spectrum herbicides which paved the way for the farmers to shift from conventional transplanting to direct seeded rice (DSR) culture. Therefore, considering the emergence of diverse weed types in *kharif* season, the purpose cannot be solved by one-time application of herbicide alone. Therefore, there is every need to apply more than one herbicide in combination or in sequence, which can offer greater promise in managing complex and diverse weed flora in DSR (Raj *et al*., 2013) [15].
Among different nutrients, nitrogen being the most important, the efficacy of which depends amongst others, the crop-weed dynamics in the growing ecosystem. Deficiency of even a single essential micronutrient may disturb the plant developmental cascades and cause substantial reduction in crop yield (Tripathi *et al*, 2015) [23]. In direct seeding, availability of several nutrients including N, P, K and micronutrients such as Zn and Fe are reported to be a constraint in realization of production potential of rice. Micronutrients, particularly zinc and iron have attained a great significance in today's intensive and exploitive agriculture which is aiming at higher crop productivity.

Materials and methods
A field experiment was conducted during *kharif*, 2018 and 2019 at Agricultural College Farm, Naira, Srikakulam, Andhra Pradesh. The experiment was laid out in split-split plot design with three replications. The weed management subjected to main plots, nutrient management in sub plots while, application of micronutrients to sub-sub plots. Experiment was comprised of four weed control methods, *viz*., W_1: Unweeded check, W_2: Hand weeding twice at 20 and 40 DAS, W_3: Pyrazosulfuron ethyl @ 20 g a.i ha^{-1} at 8-12 DAS *fb*.florpyrauxifen-benzyl @ 31.25 g a.i ha^{-1} at 25 DAS and W_4: Bispyribac sodium @ 150 g a.i ha^{-1} at 20 DAS *fb*. 2,4-D amine salt @ 600 g a.i ha^{-1} + fenoxyprop-ethyl with safener @ 150 g a.i ha^{-1} at 40-45 DAS, four nutrient management practices, *viz*., N_1: Foliar application of 19-19-19 @ 1% at 20 DAS and 2% at 40

DAS *fb*.75% RDF from conversion onwards in three splits, N_2: Foliar application of 19-19-19 @ 1% at 20 DAS and KNO_3 @ 2% at 40 DAS *fb*.75% RDF from conversion onwards in three splits, N_3: 100% RDF (Entire P through SSP, ⅓rd N and ½ K as basal and remaining N and K through top dressing as per recommendation) and N_4: Farmers practice and three micronutrients application *viz.*, M_1: $ZnSO_4$ @ 50 kg ha^{-1}, M_2: Foliar application of $ZnSO_4$ @ 0.2% twice at 20 and 40 DAS and M_3: Foliar application of $ZnSO_4$ @ 0.2% and $FeSO_4$ @ 0.5% each at 20 and 40 DAS. 'MTU-1001' variety of rice was used for seeding of rice. The soil was sandy clay loam in texture, alkaline in reaction, low in organic carbon and available nitrogen and medium in available phosphorus and available potassium.

Results and discussion

Effect on weed

Total weed density

A gradual and progressive increase in the total weed population was noticed at all stages of sampling during both the years of study. All the weed management practices were found to reduce total weed density over weedy check. At 60 DAS and at harvest, significantly lesser total weed density was noticed due to application of bispyribac sodium *fb.* 2,4-D amine salt + fenoxyprop-ethyl with safener which was however, comparable with pyrazosulfuron ethyl *fb.* florpyrauxifen-benzyl and hand weeding twice, where application of bispyribac sodium *fb.* 2,4-D amine salt + fenoxyprop-ethyl with safener was in turn on a par with hand weeding twice. Application of bispyribac sodium *fb.* 2,4-D amine salt + fenoxyprop-ethyl with safener could result in comparable performance to that of pyrazosulfuron ethyl *fb.* florpyrauxifen-benzyl in suppression of total weed population which involves application of three herbicides in a row at 20 days interval and both were found parity with hand weeding twice. Better performance of pyrazosulfuron, pendimethalin, flufenacet and bispyribac in reducing total weed density has also been reported by Kumar *et al.* (2013) [9], Rawat *et al*. (2012). Nutrient management practices were found to influence total weed density to a statistically measurable magnitude. Significantly lower total weed density was noticed with farmers practice which was however, on a par with foliar application of 19-19-19 and KNO_3 *fb.* 75% RDF and foliar application of 19-19-19 twice *fb.* 75% RDF. Application of 100% RDF registered the highest total weed density among the nutrient management practices. It might be due to better competitive ability of weeds to enjoy the 1/3rd of the nitrogen applied as basal at the time of sowing to record the highest total weed density. These results are in conformity with the findings of Chaudhary *et al.* (2011) [3]. As regards application of micronutrients, significantly lower total weed density was observed in plots which received foliar $ZnSO_4$ and $FeSO_4$ which was however, comparable with foliar feeding of $ZnSO_4$ twice during both the years of investigation and pooled mean. Basal application of $ZnSO_4$ @ 50 kg ha^{-1} registered maximum total weed density at all sampling intervals during successive years and pooled mean. Basal dressing of $ZnSO_4$ might have provided early opportunity for the growth of weeds over other two micronutrient management practices where, the micro nutrients are supplied at later stage through foliage, leaving negligible amounts available to the weeds growing underneath for their absorption.

Effect on crop

Significantly taller plants and higher SPAD meter readings were recorded with application of pyrazosulfuron ethyl *fb.* florpyrauxifen-benzyl which was however, found parity with bispyribac sodium *fb.* 2,4-D amine salt + fenoxyprop-ethyl with safener. Shortest plants and lowest SPAD readings were noticed in the plots which were unweeded. Significantly taller plants as well as higher values of SPAD readings observed with sequential application of herbicides might be due to prolonged suppressive effect of herbicides on the growth of weeds and created better weed free environment to make the growth resources available to the crop plants for rapid cell division and elongation of internodal length (Saravanane *et al*. 2016 and Ramachandiran and Balasubramanian, 2012) [19, 16].

Significantly taller plants and higher values for SPAD readings were observed with 100% RDF while, the differences in plant height among 100% RDF, foliar application of 19-19-19 twice *fb.* 75% RDF and foliar application of 19-19-19 and KNO_3 *fb.* 75% RDF were found on a par with each other and significantly superior to farmers practice. Basal application of 1/3rd N of the 100% RDF might have given early lead at tillering to sustain better in the early phase. Similar findings were reported by Ali *et al.* (2014) [1] and Parashivamurthy *et al*. (2012) [14].

Application of $ZnSO_4$ @ 50 kg ha^{-1} produced significantly taller plants and higher SPAD meter readings and was comparable with foliar feeding of $ZnSO_4$ twice. Significantly shorter plants and lower SPAD readings were found in plots which received $ZnSO_4$ and $FeSO_4$ through foliar feeding. Basal $ZnSO_4$ might have created a favourable nutrio-physiology right from beginning of crop growth resulted in producing taller plants compared to rest of the treatments. Adequate Zn nutrition is essential for meristamatic activity due to enhanced levels of auxins for which Zn remains as a precursor. The results are in agreement with those reported by Humaira *et al.* (2015) [7].

Larger number of productive tillers m^{-2} was noticed with pyrazosulfuron ethyl *fb.*florpyrauxifen-benzyl which was however, found parity with bispyribac sodium *fb.* 2,4-D amine salt + fenoxyprop-ethyl with safener which in turn found on a par with hand weeding twice during both the years of study and pooled mean. Minimum number of productive tillers m^{-2} was observed in weedy check. Continuous and heavy robbing of nutrients in weedy check plots might have reduced total number of tillers and their subsequent conversion to productive tillers (Neeshu Joshi *et al.* 2015) [13].

Significantly higher number of tillers m^{-2} were registered with 100% RDF which was however, comparable with foliar application of 19-19-19 twice *fb.*75% RDF and foliar application of 19-19-19 and KNO_3 *fb.*75% RDF. Significantly higher number of productive tillers m^{-2} could be attributed to the fact that the regular supply of nutrients especially, nitrogen either as basal or foliage might have enabled accumulation of required levels of tissue nitrogen in rice to produce ample amounts of photosynthates to support the total tillers to get converted to productive tillers with advancement of age. The productive tiller number m^{-2} was minimum with farmers practice. The findings obtained in the present study are in agreement with those reported by Srinivasagam and Stephan, 2013 [22].

Micronutrient management practices were found to influence the productive tiller number m^{-2} of rice to a statistically perceptible magnitude. Basal application of $ZnSO_4$ @ 50 kg ha^{-1}produced significantly higher numbers of productive tillers m^{-2} which were however, comparable with foliar application of $ZnSO_4$ twice during both the years and pooled mean. Significantly large number of productive tillers might be due to improved metabolic activity with Zn that enhanced the floral primordial development in many tillers.

Significantly lesser number of productive tillers m^{-2} were observed with foliar application of $ZnSO_4$ and $FeSO_4$.

Significant disparities in the grain and straw yield of rice was observed due to weed control methods and application of major and micronutrients. However, the interaction effects among these treatments were not statistically measurable. Significantly higher grain and straw yield of rice was recorded with pyrazosulfuron ethyl *fb.*florpyrauxifen-benzyl which was however, comparable with bispyribac sodium *fb.* 2,4-D amine salt + fenoxyprop-ethyl and both were significantly superior to weedy check (W_1) during both the years of study and pooled mean. Detrimental effect of sequential application of herbicides on weed growth and the resultant enhancement of grain yield of rice might be due to initial competition offered by weeds up to 20 DAS and the subsequent flushes of weeds after first weeding till the second weeding was carried out at 40 DAS in hand weeding. Similar views were also expressed by Chandra Prakash *et al*. (2013) [2] and Singh and Singh (2010) [21].

Application of 100% RDF registered significantly higher grain and straw yield which was however, found parity with foliar application of 19-19-19 twice *fb.*75% RDF and foliar application of 19-19-19 and KNO_3 *fb.*75% RDF during successive years of experimentation and pooled mean. The higher grain and straw yield obtained with 100% RDF could be attributed to the favourable influence of steady, consistent and adequate availability of nutrients during the required stages of crop growth, favouring the production of photosynthates coupled with better partitioning to the sink, under higher level of nutrition. The grain yield associated with Farmers practice was found to be the lowest and found inferior to rest of the nutrient management practices. These results are in conformity with findings of Malla Reddy *et al.* (2012) [11].

Maximum grain and straw yield was realized with basal application of $ZnSo_4$ @ 50 kg ha^{-1} which was however, comparable with foliar feeding of $ZnSO_4$ twice. Significantly higher grain yield associated with Soil or foliar application of $ZnSO_4$ could be attributed to improved growth and yield parameters through adequate availability of nutrients which in turn might have favourably influenced physiological processes and build up of photosynthates. The grain and straw yields realized with foliar application of $ZnSO_4$ and $FeSO_4$ was found to be minimum during both the years of study and pooled mean. These results were conformity with those of Meena and Fathima (2017) [12].

Table 1: Total weed density (No. m^{-2}) at 60 DAS in dry direct down rice as influenced by weed control methods, nutrient management practices and application of micronutrients

Treatments		Total weed density (No. m^{-2})		
		2018	**2019**	**Pooled**
Weed Control Methods (W)				
W_1	Unweeded check	17.69 (313.3)	18.21 (331.9)	17.95 (322.6)
W_2	Hand weeding twice at 20 and 40 DAS	13.03 (170.8)	13.74 (188.8)	13.40 (179.8)
W_3	Pyrazosulfuron ethyl @ 20 g a.i ha^{-1} at 8-12 DAS *fb.* florpyrauxifen-benzyl @ 31.25 g a.i ha^{-1} at 25 DAS	12.70 (161.5)	13.62 (185.5)	13.17 (173.5)
W_4	Bispyribac sodium @ 150 g a.i ha^{-1} at 20 DAS *fb.* 2,4-D amine salt @ 600 g a.i ha^{-1} + fenoxyprop-ethyl with safener @ 150 g a.i ha^{-1} at 40-45 DAS	12.54 (157.6)	13.24 (178.6)	12.90 (166.7)
SEm ±		0.24	0.18	0.30
CD (P = 0.05)		0.82	0.63	1.03
CV (%)		10.22	7.44	12.50
Nutrient Management Practices (N)				
N_1	Foliar application of 19-19-19 @ 1% at 20 DAS and 2% at 40 DAS *fb.* 75% RDF from conversion onwards in three splits	13.85 (197.6)	14.74 (221.4)	14.31 (209.5)
N_2	Foliar application of 19-19-19 @ 1% at 20 DAS and KNO_3 @ 2% at 40 DAS *fb.* 75% RDF from conversion onwards in three splits	13.90 (197.2)	14.55 (215.6)	14.23 (206.4)
N_3	100% RDF (Entire P through SSP, ⅓rd N and ½ K as basal and remaining N and K through top dressing as per recommendation)	14.75 (222.5)	15.38 (240.9)	15.07 (231.7)
N_4	Farmers practice (Entire P, ½ N and K immediately after conversion, remaining N and K at PI stage)	13.48 (185.9)	14.15 (206.9)	13.82 (195.0)
SEm ±		0.16	0.13	0.13
CD (P = 0.05)		0.46	0.38	0.38
CV (%)		6.79	5.34	5.43
Micronutrients (M)				
M_1	$ZnSO_4$ @ 50 kg ha^{-1}	14.48 (214.0)	15.04 (232.8)	14.77 (222.4)
M_2	Foliar application of $ZnSO_4$ @ 0.2% twice at 20 and 40 DAS	13.82 (195.5)	14.59 (216.8)	14.21 (206.1)
M_3	Foliar application of $ZnSO_4$ @ 0.2% and $FeSO_4$ @ 0.5% each at 20 and 40 DAS	13.68 (192.8)	14.48 (214.0)	14.10 (203.4)
SEm ±		0.14	0.11	0.14
CD (P = 0.05)		0.41	0.31	0.39
CV (%)		7.10	5.09	6.58
INTERACTION				
WXN				
SEm ±		0.32	0.26	0.26
CD (P = 0.05)		NS	NS	NS
WXM				
SEm ±		0.29	0.22	0.27
CD (P = 0.05)		NS	NS	NS
NXM				
SEm ±		0.29	0.22	0.27
CD (P = 0.05)		NS	NS	NS
WXNXM				
SEm ±		0.57	0.43	0.55
CD (P = 0.05)		NS	NS	NS

Data were subjected to square root transformation $\sqrt{x}$ +0.5. Figures in parenthesis are original values

Table 2: Plant height (cm) and SPAD meter readings of dry direct sown rice at harvest as influenced by weed control methods, nutrient management practices and application of micronutrients

Treatments		Plant height (cm)			SPAD meter readings		
		2018	2019	POOLED	2018	2019	POOLED
Weed Control Methods (W)							
W_1	Unweeded check	83.20	80.11	81.65	11.05	10.80	10.93
W_2	Hand weeding twice at 20 and 40 DAS	98.14	94.50	96.32	12.73	12.45	12.59
W_3	Pyrazosulfuron ethyl @ 20 g a.i ha^{-1} at 8-12 DAS *fb.* florpyrauxifen-benzyl @ 31.25 g a.i ha^{-1} at 25 DAS	108.41	104.45	106.43	13.76	13.46	13.61
W_4	Bispyribac sodium @ 150 g a.i ha^{-1} at 20 DAS *fb.* 2,4-D amine salt @ 600 g a.i ha^{-1} + fenoxyprop-ethyl with safener @ 150 g a.i ha^{-1} at 40-45 DAS	102.55	98.76	100.66	13.30	13.01	13.15
SEm ±		2.02	1.84	1.84	0.18	0.19	0.19
CD (P = 0.05)		6.99	6.37	6.37	0.63	0.66	0.64
CV (%)		12.37	11.70	11.47	8.59	9.14	8.86
Nutrient Management Practices (N)							
N_1	Foliar application of 19-19-19 @ 1% at 20 DAS and 2% at 40 DAS *fb.* 75% RDF from conversion onwards in three splits	102.47	98.68	100.57	12.91	12.63	12.77
	N_2Foliar application of 19-19-19 @ 1% at 20 DAS and KNO_3 @ 2% at 40 DAS *fb.* 75% RDF from conversion onwards in three splits	101.98	98.22	100.10	12.85	12.57	12.71
N_3	100% RDF (Entire P through SSP, ⅓rd N and ½ K as basal and remaining N and K through top dressing as per recommendation)	103.75	99.92	101.83	13.08	12.80	12.94
N_4	Farmers practice (Entire P, ½ N and K immediately after conversion, remaining N and K at PI stage)	84.11	81.00	82.55	11.98	11.72	11.85
SEm ±		0.90	0.69	1.39	0.09	0.09	0.09
CD (P = 0.05)		2.62	2.02	4.06	0.27	0.26	0.27
CV (%)		5.49	4.40	8.68	4.45	4.23	4.34
Micronutrients (M)							
M_1	$ZnSO_4$ @ 50 kg ha^{-1}	100.13	96.43	98.28	12.90	12.61	12.75
M_2	Foliar application of $ZnSO_4$ @ 0.2% twice at 20 and 40 DAS	98.91	95.27	97.09	12.79	12.51	12.65
M_3	Foliar application of $ZnSO_4$ @ 0.2% and $FeSO_4$ @ 0.5% each at 20 and 40 DAS	95.20	91.66	93.43	12.44	12.17	12.30
SEm ±		0.67	0.36	0.99	0.06	0.07	0.06
CD (P = 0.05)		1.88	1.03	2.81	0.17	0.19	0.18
CV (%)		4.71	2.68	7.16	3.32	3.75	3.54
INTERACTION							
WXN							
SEm ±		1.79	1.39	2.78	0.19	0.18	0.18
CD (P = 0.05)		NS	NS	NS	NS	NS	NS
WXM							
SEm ±		1.33	0.73	1.99	0.12	0.13	0.13
CD (P = 0.05)		NS	NS	NS	NS	NS	NS
NXM							
SEm ±		1.33	0.73	1.99	0.12	0.13	0.13
CD (P = 0.05)		NS	NS	NS	NS	NS	NS
WXNXM							
SEm ±		2.67	1.46	3.98	0.24	0.27	0.26
CD (P = 0.05)		NS	NS	NS	NS	NS	NS

Table 3: Number of productive tillers m^{-2}, grain yield (kg ha^{-1}) and straw yield (kg ha^{-1}) of dry direct sown rice as influenced by weed control methods, nutrient management practices and application of micronutrients

Treatments		Number of productive tillers m^{-2}			Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})		
		2018	2019	Pooled	2018	2019	POOLED	2018	2019	POOLED
Weed Control Methods (W)										
W_1	Unweeded check	305	298	302	4023	3936	3979	5905	5538	5721
W_2	Hand weeding twice at 20 and 40 DAS	413	404	408	5328	5107	5218	6965	6458	6712
W_3	Pyrazosulfuron ethyl @ 20 g a.i ha^{-1} at 8-12 DAS *fb.* florpyrauxifen-benzyl @ 31.25 g a.i ha^{-1} at 25 DAS	460	450	455	6055	5737	5896	7780	7300	7540
W_4	Bispyribac sodium @ 150 g a.i ha^{-1} at 20 DAS *fb.* 2,4-D amine salt @ 600 g a.i ha^{-1} + fenoxyprop-ethyl with safener @ 150 g a.i ha^{-1} at 40-45 DAS	436	427	431	5733	5435	5584	7441	6980	7211
SEm ±		7.21	7.44	7.35	113.93	92.72	97.03	136.28	149.95	123.50
CD (P = 0.05)		24.96	25.74	25.45	394.26	320.86	335.77	471.60	518.90	427.37
CV (%)		10.72	11.31	11.05	12.66	10.98	11.13	11.61	13.62	10.86
Nutrient Management Practices (N)										
N_1	Foliar application of 19-19-19 @ 1% at 20 DAS and 2% at 40 DAS *fb.* 75% RDF from conversion onwards in three splits	415	406	411	5554	5210	5382	7243	6794	7018
N_2	Foliar application of 19-19-19 @ 1% at 20 DAS and KNO_3 @ 2% at 40 DAS *fb.* 75% RDF from conversion onwards in three splits	413	404	409	5527	5185	5356	7206	6760	6983
N_3	100% RDF (Entire P through SSP, ⅓rd N and ½ K as basal and remaining N and K through top dressing as per recommendation)	421	412	416	5626	5277	5452	7341	6886	7113
N_4	Farmers practice (Entire P, ½ N and K immediately after conversion, remaining N and K at PI stage)	365	357	361	4892	4590	4741	6383	5987	6185
SEm ±		4.71	3.87	3.74	61.56	35.89	63.92	61.76	71.97	53.46
CD (P = 0.05)		13.75	11.30	10.91	179.68	104.76	186.57	180.28	210.08	156.04
CV (%)		7.00	5.89	5.62	6.84	4.25	7.33	5.26	6.54	4.70
Micronutrients (M)										
M_1: $ZnSO_4$ @ 50 kg ha^{-1}		410	401	406	5550	5181	5366	7175	6730	6952

M2: Foliar application of $ZnSO_4$ @ 0.2% twice at 20 and 40 DAS	406	398	402	5446	5109	5277	7126	6684	6905
M3: Foliar application of $ZnSO_4$ @ 0.2% and $FeSO_4$ @ 0.5% each at 20 and 40 DAS	394	385	390	5204	4907	5056	6828	6406	6617
SEm ±	3.06	1.65	1.80	46.28	26.61	48.85	55.79	70.90	41.87
CD (P = 0.05)	8.63	4.65	5.07	130.76	75.17	138.02	157.61	200.31	118.30
CV (%)	5.25	2.89	3.12	5.94	3.64	6.47	5.49	7.43	4.25
Interaction									
WXN									
SEm ±	9.42	7.75	7.48	123.12	71.78	127.84	123.53	143.95	106.92
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
WXM									
SEm ±	6.11	3.29	3.59	92.57	53.21	97.70	111.57	141.80	83.75
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
NXM									
SEm ±	6.11	3.29	3.59	92.57	53.21	97.70	111.57	141.80	83.75
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
WXNXM									
SEm ±	12.22	6.59	7.18	185.14	106.43	195.41	223.15	283.60	167.50
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Zn and FE uptake by grain and straw

Uptake of zinc and iron by grain and straw was found to be significantly higher with pyrazosulfuron ethyl *fb.* florpyrauxifen-benzyl which was however, on a par with bispyribac sodium *fb.* 2,4-D amine salt + fenoxyprop-ethyl with safener during both the years of investigation and pooled mean. Superior weed control obtained with the two chemical weed management practices and the associated favourable effect on grain yield might have enabled rice crop to absorb adequate quantities of micronutrients and its translocation to the sink in the later part of the life cycle of crop. Zinc and iron uptake by grain and straw was observed to be significantly lower in unweeded check.

Significant increase in zinc and iron uptake by grain and straw found with foliar application of 19-19-19 twice *fb.* 75% RDF which was however, on a par with foliar application of 19-19-19 and KNO_3 *fb.* 75% RDF and 100% RDF and all were significantly superior to farmers practice. Significantly lower uptake values by grain registered with farmers practice might be due to sub-optimal nutrient status experienced by rice crop in the first 40 days of life cycle to produce poor growth stature and its consequent effect on grain yield to record lower zinc uptake.

Distinct disparities were noticed among micronutrient management practices in influencing uptake of zinc by grain and straw in dry direct sown rice. Significantly higher uptake of zinc by grain and straw was observed with basal application of $ZnSO_4$ @ 50 kg ha^{-1} and it was minimum with foliar feeding of $ZnSO_4$ and $FeSO_4$ each at 20 and 40 DAS) while, in case of iron uptake by grain and straw foliar application of $ZnSO_4$ @ 0.2% and $FeSO_4$ @ 0.5% each at 20 and 40 DAS obtained significantly higher values over other treatments except in the case of iron uptake by straw where, foliar feeding of $ZnSO_4$ and $FeSO_4$ found comparable with basal $ZnSO_4$ @ 50 kg ha^{-1}. Basal dressing of $ZnSO_4$ might have enabled rice to enjoy adequate levels of zinc to maintain sufficient concentration of this element in the tissue. Significantly higher yield realized might also be responsible for recording higher uptake of values for zinc by grain and straw. These results are in accordance with the findings of Ghoneim (2016) [5] and Jadhav *et al.* (2014) [8]. Significantly higher values for uptake of iron by grain associated with foliar spraying of $ZnSO_4$ and $FeSO_4$ might be due to higher concentration of iron in the tissue due to foliar feeding of $FeSO_4$ @ 0.5% at 40 DAS and its translocation to grain and straw. These findings are in agreement with the results of Gohil *et al.* (2017) [6] and Yadav *et al.* (2011) [24].

From the study, it can be concluded that sequential application of pyrazosulfuron ethyl @ 20 g a.i ha^{-1} at 8-12 DAS *fb.*florpyrauxifen-benzyl @ 31.25 g a.i ha^{-1} at 25 DAS along with application of 100% RDF and basal application of $ZnSO_4$ @ 50 kg ha^{-1} or foliar application of $ZnSO_4$ and $FeSO_4$ twice at 20 and 40 DAS was found to be highly effective and economical for better weed control and nutrient management to enable reaping higher yields and economic returns.

Table 4: Uptake of zinc and iron (g ha^{-1}) by grain of dry direct sown rice as influenced by weed control methods, nutrient management practices and application of micronutrients

Treatments		Zinc (g ha^{-1})			Iron (g ha^{-1})		
		2018	2019	POOLED	2018	2019	POOLED
Weed Control Methods (W)							
W_1	Unweeded check	94.87	114.42	104.65	866.83	798.60	832.71
W_2	Hand weeding twice at 20 and 40 DAS	110.63	133.44	122.03	1010.61	931.18	970.90
W_3	Pyrazosulfuron ethyl @ 20 g a.i ha^{-1} at 8-12 DAS *fb.* florpyrauxifen-benzyl @ 31.25 g a.i ha^{-1} at 25 DAS	122.25	147.50	134.88	1116.42	1028.93	1072.68
W_4	Bispyribac sodium @ 150 g a.i ha^{-1} at 20 DAS *fb.* 2,4-D amine salt @ 600 g a.i ha^{-1} + fenoxyprop-ethyl with safener @ 150 g a.i ha^{-1} at 40-45 DAS	115.62	139.47	127.54	1056.06	973.14	1014.60
SEm ±		2.38	2.55	2.42	20.72	16.81	18.38
CD (P = 0.05)		8.23	8.83	8.36	71.69	58.19	63.61
CV (%)		12.87	11.45	11.86	12.28	10.81	11.34
Nutrient Management Practices (N)							
N_1	Foliar application of 19-19-19 @ 1% at 20 DAS and 2% at 40 DAS *fb.* 75% RDF from conversion onwards in three splits	114.06	137.59	125.82	1041.19	959.40	1000.29
N_2	Foliar application of 19-19-19 @ 1% at 20 DAS and KNO_3 @ 2% at 40 DAS *fb.* 75% RDF from conversion onwards in three splits	113.49	136.92	125.20	1035.99	954.62	995.31
N_3	100% RDF (Entire P through SSP, ⅓rd N and ½ K as basal and remaining N and K through top dressing as per recommendation)	115.55	139.37	127.46	1054.72	971.81	1013.27
N_4	Farmers practice (Entire P, ½ N and K immediately after conversion, remaining N and K at PI stage)	100.27	120.97	110.62	918.02	846.02	882.02
SEm ±		1.18	0.93	0.95	11.21	6.64	8.22
CD (P = 0.05)		3.45	2.72	2.78	32.71	19.37	23.99

CV (%)	6.41	4.18	4.68	6.64	4.27	5.07
Micronutrients (M)						
M$_1$: $ZnSO_4$ @ 50 kg ha^{-1}	137.25	159.68	148.47	1026.64	958.09	992.36
M$_2$: Foliar application of $ZnSO_4$ @ 0.2% twice at 20 and 40 DAS	105.02	132.83	118.93	942.11	858.26	900.19
M$_3$: Foliar application of $ZnSO_4$ @ 0.2% and $FeSO_4$ @ 0.5% each at 20 and 40 DAS	90.25	108.62	99.44	1068.69	982.55	1025.62
SEm ±	1.02	0.89	0.86	7.90	4.74	5.42
CD (P = 0.05)	2.88	2.50	2.43	22.32	13.39	15.32
CV (%)	6.37	4.59	4.86	5.41	3.52	3.86
INTERACTION						
WXN						
SEm ±	2.37	1.86	1.91	22.42	13.27	16.44
CD (P = 0.05)	NS	NS	NS	NS	NS	NS
WXM						
SEm ±	2.04	1.77	1.72	15..80	9.48	10.85
CD (P = 0.05)	NS	NS	NS	NS	NS	NS
NXM						
SEm ±	2.04	1.77	1.72	15.80	9.48	10.85
CD (P = 0.05)	NS	NS	NS	NS	NS	NS
WXNXM						
SEm ±	4.08	3.54	3.43	31.60	18.95	21.70
CD (P = 0.05)	NS	NS	NS	NS	NS	NS

Table 5: Uptake of zinc and iron (g ha^{-1}) by straw of dry direct sown rice as influenced by weed control methods, nutrient management practices and application of micronutrients

Treatments		Zinc (g ha^{-1})			Iron (g ha^{-1})		
		2018	**2019**	**POOLED**	**2018**	**2019**	**POOLED**
Weed Control Methods (W)							
W$_1$	Unweeded check	159.57	170.36	164.96	2362.08	2187.63	2274.86
W$_2$	Hand weeding twice at 20 and 40 DAS	190.40	203.30	196.85	2818.56	2610.75	2714.66
W$_3$	Pyrazosulfuron ethyl @ 20 g a.i ha^{-1} at 8-12 DAS *fb.* florpyrauxifen-benzyl @ 31.25 g a.i ha^{-1} at 25 DAS	210.24	224.54	217.39	3112.24	2883.50	2997.87
W$_4$	Bispyribac sodium @ 150 g a.i ha^{-1} at 20 DAS *fb.* 2,4-D amine salt @ 600 g a.i ha^{-1} + fenoxyprop-ethyl with safener @ 150 g a.i ha^{-1} at 40-45 DAS	201.07	214.72	207.89	2976.54	2757.39	2866.96
SEm ±		3.54	4.58	4.04	55.13	58.37	56.68
CD (P = 0.05)		12.26	15.85	14.00	190.79	202.00	196.14
CV (%)		11.17	13.52	12.33	11.74	13.42	12.53
Nutrient Management Practices (N)							
N	Foliar application of 19-19-19 @ 1% at 20 DAS and 2% at 40 DAS *fb.* 75% RDF from conversion onwards in three splits	195.84	209.13	202.48	2896.74	2683.51	2790.12
N$_2$	Foliar application of 19-19-19 @ 1% at 20 DAS and KNO_3 @ 2% at 40 DAS *fb.* 75% RDF from conversion onwards in three splits	194.83	208.06	201.45	2881.76	2669.73	2775.75
N$_3$	100% RDF (Entire P through SSP, ⅓rd N and ½ K as basal and remaining N and K through top dressing as per recommendation)	198.50	211.95	205.22	2936.12	2719.69	2827.91
N$_4$	Farmers practice (Entire P, ½ N and K immediately after conversion, remaining N and K at PI stage)	172.10	183.78	177.94	2554.81	2366.34	2460.57
SEm ±		1.67	2.22	1.88	24.88	27.34	25.78
CD (P = 0.05)		4.87	6.49	5.50	72.61	79.79	75.25
CV (%)		5.26	6.57	5.75	5.30	6.29	5.70
Micronutrients (M)							
M$_1$	$ZnSO_4$ @ 50 kg ha^{-1}	235.34	249.01	242.17	2855.63	2638.14	2746.89
M$_2$	Foliar application of $ZnSO_4$ @ 0.2% twice at 20 and 40 DAS	188.14	200.53	194.33	2715.14	2519.95	2617.54
M$_3$	Foliar application of $ZnSO_4$ @ 0.2% and $FeSO_4$ @ 0.5% each at 20 and 40 DAS	147.48	160.15	153.82	2881.30	2671.37	2776.33
SEm ±		1.32	2.14	1.29	23.64	27.21	18.17
CD (P = 0.05)		3.72	6.06	3.65	66.78	76.86	51.33
CV (%)		4.79	7.31	4.54	5.81	7.22	4.64
INTERACTION							
WXN							
SEm ±		3.34	4.45	3.77	49.75	54.68	51.56
CD (P = 0.05)		NS	NS	NS	NS	NS	NS
WXM							
SEm ±		2.63	4.29	2.58	47.27	54.41	36.34
CD (P = 0.05)		NS	NS	NS	NS	NS	NS
NXM							
SEm ±		2.63	4.29	2.58	47.27	54.41	36.34
CD (P = 0.05)		NS	NS	NS	NS	NS	NS
WXNXM							
SEm ±		5.27	8.57	5.16	94.55	108.82	72.67
CD (P = 0.05)		NS	NS	NS	NS	NS	NS

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