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Effect of nitrogen levels and herbicides on major nutrients uptake and recovery by finger millet in sodic soil

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Abstract
Finger millet is an essential diet on everyday intake. It's the third most food crop among millets. It requires less water to produce the yield and is recommended as a tolerant crop for sodic soil. Hence, an experiment was conducted with application of various herbicides in combination as subplots and two nitrogen levels viz., 100% RDF and 125% N RDF in split plot design to study their individual effect and their interaction. The results showed that application of 125% N RDF, PE oxyfluorfen + EPOE bispyribac sodium and 125% N plus PE oxyfluorfen + EPOE bispyribac sodium recorded higher primary nutrients uptake. The utrients recovery was also arrived and found to be higher comparatively in pendimethalin plots. Results revealed that the application of pre- emergence and post emergence herbicides have higher recovery of N, P and K in finger millet due to the maintainenence of weed free condition for longer extent along with 125 % N level through boosting the crop growth and improving the nutrients absorption.

Keywords: Nitrogen level, herbicides, uptake, nutrients use efficiency, Sodic soil

Introduction
Finger millet (*Eleusine coracana* (L.) Gaertn) is a staple food crop grown in the semi-arid tropics of South Asia and Africa and ranked fourth globally in importance among the millets, after sorghum, pearl millet, and foxtail millet (Gupta *et al.*, 2012) [7]. It is cultivated in more than 25 countries, mainly in Africa and Asia (Dass *et al.*, 2013) [4]. The global production of millet is about 30.73 million tonnes out of which 11.42 million tonnes are produced in India. The production and productivity of finger millet in India is 1.98 million tonnes and 1661 kg/ha, respectively. It is cultivated mainly in Karnataka, and Tamil Nadu besides Andhra Pradesh, Maharastra, Bihar and Odisha (Sakamma *et al.*, 2018) [20].
Ragi has become an indispensable component of dry land farming systems (Thilakarathna *et al.*, 2015) [22] and is also recommended as tolerant crop for cultivation in salt affected soils. The salt affected soil in India is around 6.74 m/ha, among which 0.36 m ha is found in Tamil Nadu. Sodicity of soil affect the yield and biomass production of finger millet (Qadir *et al.*, 1996) [17]. High osmotic stress, specific ion toxicity and nutritional disorders are observed in plants grown under sodic soil (Qadir *et al.*, 2002) [18].
Salt-affected soils are characterized by high levels of water-soluble salts, high pH and high sodium (Na) contents which inhibit plant growth due to salt-induced water stress, specific ion toxicity, ion imbalance or nutritional disorders, oxidative stress, and hormonal imbalances (Munns *et al.*, 2006) [14]. In saline-sodic soils, the availability and absorption of plant nutrients is severely limited to sustain high crop production due to ion interactions, specially low nitrogen (N) because of its leaching as NO_3 at high soil pH, volatilization and de-nitrification losses (Marschner 2011) [13]. All these factors individually or in combination with each other limits N-use-efficiency (NUE) and the extent of this limitation depends on the salinity/ sodicity levels, crop types and species and soil physic-chemical properties (Grattan *et al.*, 1999) [9].
Finger millet is high nitrogen efficient crop and can flourish even on no nitrogen inputs yetaccumulates high quality proteins enriched with essential amino acids in their grains (Gupta *et al.*, 2017) [8]. However increased levels of nitrogen is recommended for crops grown in sodic soil since the increased N application compensates the yield reduction due to increasing levels of exchangeable Na percentage when soil physical properties are not a limiting factor in plant growth (Ali *et al.*, 2009) [2]. Increased uptake of Ca^{2+} and Mg^{2+}, and decreased uptake of Na^+ by plants resulting from additional N application were responsible for the greater response to N at high exchangeable Na^+ levels (Murtaza *et al.*, 2017) [15]. When N application level is increased, the problem of weed menace occurs which could reduce the yield of crops up to 40%.

This warrants the frequent use of herbicides for weed management in crops which might affect the soil health and crop quality y leaving herbicide residues. Hence it is essential to study the effect of nitrogen levels and herbicides on the behavior of plant nutrient uptake in sodic soil condition.

Materials and methods

The experiment was accomplished in Anbil Dharmalingam Agricultural College and Research Institute farm, Thiruchirapalli, Tamil Nadu, India. Geographically, the experimental region was located in Cauvery delta zone of Tamil Nadu at $10^0$45' N Latitude and 78^0 36' E Longitude at an altitude of 85 m above MSL.The Soil of the experimental field was sandy clay loam in texture (sand 65.03 %, silt 8.40 % and clay 25.53 %) with pH of 8.50, EC of 0.84 dS m^{-1}, CEC of 18.30 c.mol $(p^+)kg^{-1}$ and organic carbon 0.40 %. It has low soil available nitrogen (213 kg/ha), medium in available phosphorus (11.35 kg/ha) and potassium (243 kg/ha). The finger millet variety of TRY 1, *kharif* 2018 with 102 days of duration, seed rate of 5 kg/ha and plant spacing of 30 x 15 cm depth are used for experimental study. The treatments were imposed in split plot with two N levels (M_1-100% N and M_2-125% N) in main plots and five herbicides treatments in sub plots viz., PE pendimethalin 30 EC @ 750 g/ha (S_1), PE oxyfluorfen 23.5 EC @ 50 g/ha (S_2), EPOE bispyribac sodium 10 SC @ 25 g/ha (S_3), S_1+ EPOE bispyribac sodium 10 SC @ 25 g/ha and S_2+ EPOE bispyribac sodium 10 SC @ 25 g/ha. Sub plots treatments namely herbicides were sprayed using flat fan nozzle with the spray volume of 450 L/ha.

Nitrogen fertilizer was applied in two splits and P and K were applied as basal dose. In each experimental plot, five plants were tagged in order to get the plant samples at two stages of its growth. The plant sample were collected from replicates, shade dried and oven dried at 70^0 C to obtain a constant value. Dried finger millet plant parts were powdered using willey mill separately and then analysed for N, P and K content. The nutrient uptake was worked out using the nutrient concentration and dry matter production of finger millet. The statistical analysis of the data was carried out as per Gomez *et al.* (1984) [6] using split plot design. The utilization efficiency parameters were worked as per as per Dobermann (2007) [5].

Results and discussion

The requirement of primary nutrients are essential for every crop to increase the economic yield. Finger Millet response well to nitrogen fertilizers (Gupta *et al.,* 2012, Hegde and Gowda, 1989) [7, 13]. Due salt induced water stresses in sodic soil, the uptake of applied nutrients by the crop in sodic soil is poor particularly N and hence always extra doses are applied to meet the crop demand. When additional N is applied, the weeds menace is a problem and will competer for crop uptake. If nutrients are not avialble for the crop in time, then partitioning of source-sink to economic portion is very poor and will reduce the crop yield. Hence the uptake and utilization efficiency of the major nutrients by the finger millet in sodic soil as influenced by the N levels and different herbicides and their interactions were investigated and the results are presented and discussed here.

Nitrogen Uptake

The application of N levels and herbicides and their interactions affected the N uptake significantly (Table 1 and 4) during both flowering and harvesting stages of the finger millet. All plant parts during both flowering (shoot and root) and harvesting (grain, straw and root) stages accumulated higher N under 125% N applied plots and in the combined application of PE oxyfluorfen+EPOE bispyribac sodium (S_5) among sub plots except the root at flowering stage where PE pendimethalin + EPOE bispyribac sodium showed higher N uptake. Interaction showed that the higher N uptake was accumulated by the 125%N along with PE oxyfluorfen and EPOE bispyribac sodium (M_2S_5) in all parts except grain at harvest stage. The N uptake of grain was high in PE oxyfluorfen and EPOE bispyribac sodium on sub plot treatments where as on interaction 125 % N level plus PE oxyfluorfen+ EPOE bispyribac sodium (M_2S_5) recorded higher N uptake. Similar results were obtained for the total dry matter at both the stages. Since the N applied was 25% extra at M_2, all parts accumulated higher N. Also the combined application of PE oxyfluorfen+EPOE bispyribac sodium might have increased N availabilty and uptake through controlling the broad group of weeds and then the N removal by weeds. Similar result was reported by Shanmugapriya *et al*. (2019) [22] for finger millet.

Phosphorus uptake

Uptake of phosphorus by finger millet parts during its flowering and harvest stages (Table 2 and 5) by various parts of the plant was maximum in 125% N (M_2) applied treatments and also in PE oxyfluorfen+ EPOE bispyribac sodium (S_5) on herbicide treatments. The interaction effect of 125% N with PE pendimethalin + EPOE bispyribac sodium (M_2S_4) on shoot P uptake was higher during flowering while at harvest, 125%N with PE oxyfluorfen+ EPOE bispyribac sodium (M_2S_5) accumulated higher P uptake. However the root P uptake, is maximum in PE oxyfluorfen+ EPOE bispyribac sodium (S_5) at both flowering and harvesting stage under both the main plots. Grain P uptake was also high in PE oxyfluorfen + EPOE bispyribac sodium (S_5). The maximum total P uptake was found to be in 125% N (M_2) among the nitrogen levels, PE oxyfluorfen + EPOE bispyribac sodium (S_5) and 125% N with PE pendimethalin + EPOE bispyribac sodium (M_2S_4) among the interaction effects. The higher P uptake in PE oxyfluorfen + EPOE bispyribac sodium along with 125% N could be attributed to the enhanced growth by the increased N application which inturn might have increased the P uptake. Similar result was reported by Janaki *et al.,* (2019) [11]

Potassium uptake

Similar to N and K uptake, the application of PE oxyfluorfen+EPOE bispyribac sodium recorded higher K uptake by the finger millet plant parts during flowering and harvesting stage (Table 3 and 6). On two nitrogen levels, K uptake in all parts except grain were found to higher 125%N level. Among the interaction, 125% N along with PE oxyfluorfen+EPOE bispyribac sodium acculuated higher K in all parts at both stages of crop growth. Similar to N and P uptake in grain, was higher in 125% N (M_2) plot and among the herbicide treatments, PE oxyfluorfen+EPOE bispyribac sodium (S_5) accumulated higher K uptake. The interaction 125 % N with PE pendimethalin + EPOE bispyribac sodium (M_2S_4)was found to accumulate higher K in grain as that of N and P.

Maximum uptake of all major nutirnets in all parts of finger millet attributed to the enhanced high dry matter production due to the application of 125% N and reduced weeds growth by the increased absorbance and action of the herbicides on the weeds. The enhanced dry matter production results in

increased uptake of nutrients.This findings are in accordance with Ali *et al.* (2003) [3]. Sandhya Rani *et al.* (2017) [21] also reported the same result that the higher N, P and K uptake in 150 % recommended N applied plots. From flowering stage to harvest stage, the nutrients uptake of shoot get decreased due to reduction of chlorophyll content on aging, effective translocation of nutrients to sink (grain) may reduce their uptake on harvest stage. Higher uptake in PE pendimethalin + EPOE bispyribac sodium may reduce the weed population effectively than single spray there by maintains the weed free condition to the long extent which makes the finger millet to utilizes the nutrient resources properly. This findings is in parallel with Pavithra *et al.* (2017) [16]; Ramprakash *et al.*, (2015) [19] and Khaliq *et al.*, (2013) [12]. The weed free condition acommpanied with 125 % N increased the nutrient uptake in interaction between nitrogen and herbicides so gradually higher uptake was resulted in M2S5. Moreover, weed free condition improves the crop root efficiecy and supplemental nitrogen improves the root activity. Abouziena *et al.*, (2007) [1] also reported that interaction of weed control and N levels are significant with grain index and biological yield of maize.

Nutrients Recovery

Nuutrient recovery efficiency is the amount of nutrient effectively takenup by the crop from applied nutrients. Higher the value means, higher the recovery of nutrients from soil. The hrecovery of N, P and K by shoot and root was more in S_5 under both 100% N and 125% N level as application of pre emergence oxyfluorfen and early post emergence bispyribac sodium decreased the weeds flora for longer time which enhanced the nutrient uptake capacity of finger millet (Fig 1 and Fig 2). The lowest recovery was obatined in pendimethalin treatments because single use of herbicide spray does not maintain the weed free situation for long enough, so weed competetion might have reduced the crop nutrient recovery. The recovery efficiency was high during its flowering phase than harvesting stage and suggests that the partitioning of source from shoot is to economic part was higher and can be due to the enhanced translocation of nutrients to the sink (grains) on harvest stage.

Table 1: Effect of nitrogen levels and herbicides on N uptake (kg/ha) in finger millet parts at flowering phase

Treatment (Main plots-M ; Sub plots – S)	Shoot				Root				Total			
	M_1	M_2		Mean	M_1	M_2		Mean	M_1	M_2		Mean
S_1- Pendimethalin	30.53	46.95		38.74	11.79	15.91		13.85	42.31	62.86		52.59
S_2- Oxyfluorfen	37.53	43.65		40.59	12.90	15.96		14.43	50.43	59.61		55.02
S_3- Bispyribac-sodium	41.44	52.37		46.91	13.87	17.90		15.89	55.31	70.27		62.79
S_4- S_1+bispyribac-sodium	43.65	51.14		47.40	16.04	19.88		17.96	59.70	71.02		65.36
S_5- S_2+bispyribac sodium	45.94	52.69		49.31	16.13	18.51		17.32	62.06	71.21		66.63
S_6- Control	24.75	32.24		28.50	10.88	12.93		11.90	35.63	45.17		40.40
Mean	37.31	46.51			13.60	16.85			50.91	63.36		
	M	S	M x S	S x M	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.33	0.72	0.98	1.01	0.32	0.33	0.53	0.46	0.23	0.76	1.01	1.08
CD (p=0.05)	1.42	1.49	2.29	2.11	1.37	0.68	1.53	0.97	0.97	1.59	2.22	2.25

Table 2: Effect of nitrogen levels and herbicides on P uptake (kg/ha) in finger millet parts at flowering phase

Treatments (Main plots-M ; Sub plots – S)	Shoot				Root				Total			
	M_1	M_2		Mean	M_1	M_2		Mean	M_1	M_2		Mean
S_1- Pendimethalin	9.26	15.65		12.46	5.81	7.14		6.47	15.07	22.79		18.93
S_2- Oxyfluorfen	12.51	16.11		14.31	6.10	7.14		6.62	18.61	23.25		20.93
S_3- Bispyribac-sodium	15.29	17.10		16.20	6.46	7.73		7.10	21.75	24.84		23.29
S_4- S_1+bispyribac-sodium	16.11	17.23		16.67	6.69	8.28		7.48	22.79	25.51		24.15
S_5- S_2+bispyribac sodium	15.84	17.19		16.52	7.08	8.31		7.69	22.92	25.50		24.21
S_6- Control	9.15	10.75		9.95	5.44	6.09		5.77	14.59	16.84		15.72
Mean	13.03	15.67			6.26	7.45			19.29	23.12		
	M	S	M x S	S x M	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.13	0.51	0.67	0.72	0.11	0.14	0.22	0.20	0.19	0.49	0.66	0.69
CD (p=0.05)	0.55	1.07	1.46	1.51	0.48	0.29	NS	NS	0.80	1.01	1.49	1.44

Table 3: Effect of nitrogen levels and herbicides on K uptake (kg/ha) in finger millet parts at flowering phase

Treatments (Main plots-M ; Sub plots – S)	Shoot				Root				Total			
	M_1	M_2		Mean	M_1	M_2		Mean	M_1	M_2		Mean
S_1- Pendimethalin	51.11	78.25		64.68	7.30	9.59		8.45	58.41	87.84		73.13
S_2- Oxyfluorfen	62.97	78.99		70.98	8.54	10.29		9.42	71.51	89.28		80.40
S_3- Bispyribac-sodium	74.00	83.90		78.95	8.17	11.27		9.72	82.17	95.17		88.67
S_4- S_1+bispyribac-sodium	80.55	85.59		83.07	9.74	12.31		11.02	90.29	97.90		94.09
S_5- S_2+bispyribac sodium	84.48	89.30		86.89	9.84	12.34		11.09	94.32	101.64		97.98
S_6- Control	50.51	59.71		55.11	6.40	7.75		7.08	56.91	67.46		62.19
Mean	67.27	79.29			8.33	10.59			75.60	89.88		
	M	S	M x S	S x M	M	S	M x S	S x M	M	S	M x S	S x M
SEd	1.26	1.60	2.42	2.27	0.07	0.16	0.22	0.23	1.24	1.62	2.43	2.29
CD (p=0.05)	5.42	3.34	6.51	4.73	0.31	0.33	0.511	0.47	5.32	3.38	6.46	4.77

Table 4: Effect of nitrogen levels and herbicides on N uptake (kg/ha) in finger millet parts at harvest

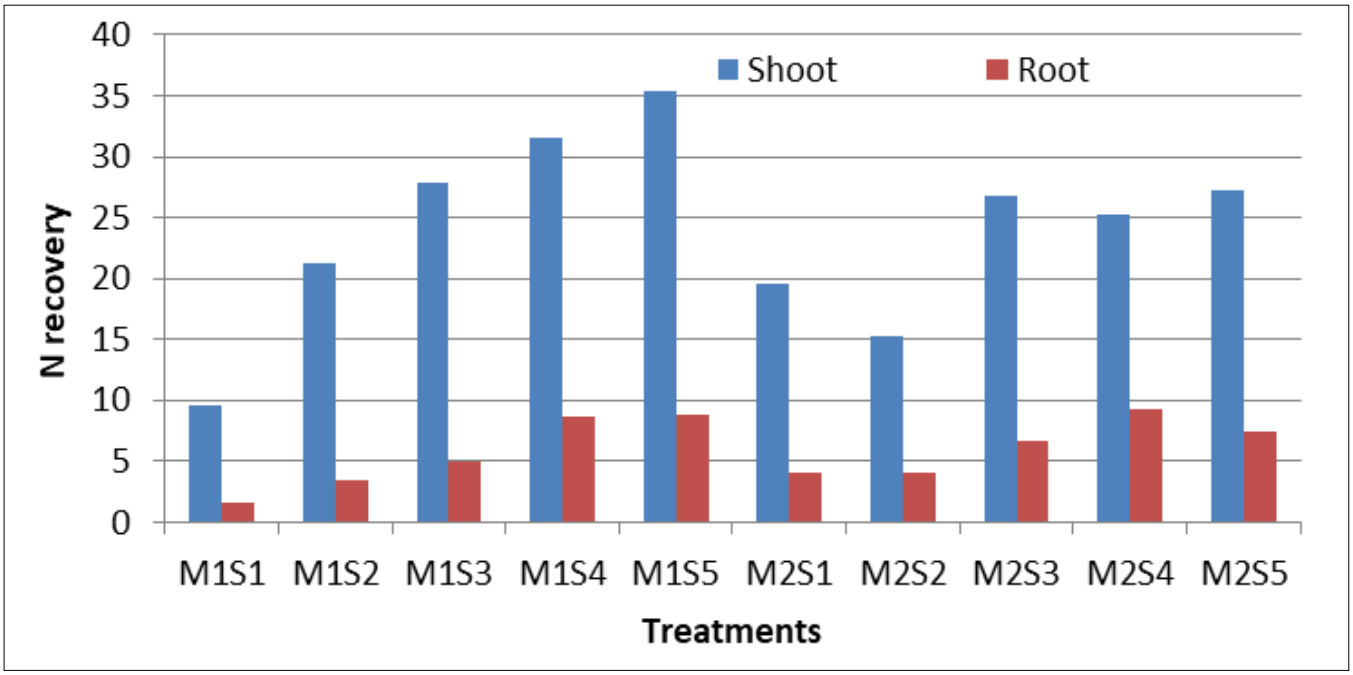
Treatments (Main plots-M ; Sub plots – S)	Grain				Straw				Root					Total		
	M_1	M_2		Mean	M_1	M_2		Mean	M_1	M_2		Mean		M_1	M_2	Mean
S_1- Pendimethalin	23.94	28.09		26.01	27.94	43.08		35.60	7.72	9.96		8.84		59.6	81.13	70.45
S_2- Oxyfluorfen	24.75	30.59		27.67	36.63	48.69		42.73	7.57	9.79		8.68		68.94	89.06	79.07
S_3- Bispyribac-sodium	25.48	27.27		26.38	41.88	50.11		45.91	7.41	10.40		8.91		74.78	87.79	81.28
S_4- S_1+bispyribac-sodium	28.83	33.60		31.22	40.83	49.55		45.11	9.29	12.90		11.09		78.95	96.05	87.40
S_5- S_2+bispyribac sodium	29.33	38.00		33.66	55.30	61.89		58.83	10.01	12.90		11.46		94.64	112.79	103.71
S_6- Control	10.59	10.61		10.60	23.05	32.05		27.41	6.74	8.22		7.55		40.38	50.88	45.56
Mean	23.82	28.03			36.91	47.12			8.04	10.70				68.77	85.85	
	M	S	M x S	S x M	M	S	M x S	S x M	M	S	M x S	S x M		M	S	M x S	S x M
SEd	0.22	0.76	0.99	1.07	0.17	0.76	1.00	1.08	0.08	0.18	0.24	0.25		0.21	1.14	1.49	1.61
CD (p=0.05)	0.92	1.58	2.19	2.23	0.75	1.59	2.16	2.25	0.32	0.37	0.56	0.53		0.88	2.38	3.17	3.37

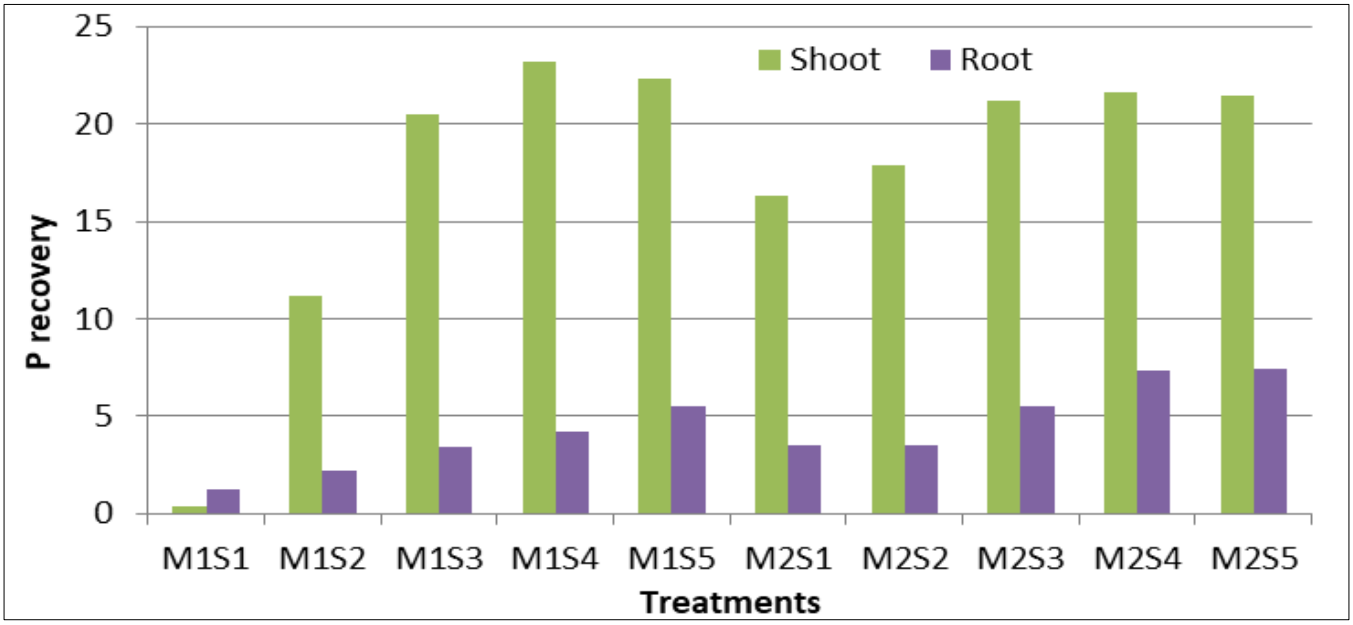
Table 5: Effect of nitrogen levels and herbicides on P uptake (kg/ha) in finger millet parts at harvest

Treatments (Main plots-M ; Sub plots – S)	Grain				Straw				Root					Total		
	M_1	M_2		Mean	M_1	M_2		Mean	M_1	M_2		Mean		M_1	M_2	Mean
S_1- Pendimethalin	10.43	12.46		11.44	13.61	17.02		15.31	4.71	6.75		5.73		28.75	36.22	32.49
S_2- Oxyfluorfen	9.31	14.85		12.08	15.26	26.22		20.74	4.90	6.82		5.86		29.48	47.88	38.68
S_3- Bispyribac-sodium	12.48	14.58		13.53	26.92	31.59		29.26	4.58	7.06		5.82		43.99	53.23	48.61
S_4- S_1+bispyribac-sodium	12.51	13.95		13.23	16.23	31.93		24.08	6.35	7.05		6.70		35.08	52.94	44.01
S_5- S_2+bispyribac sodium	11.84	14.81		13.33	21.80	30.66		26.23	6.30	8.95		7.62		39.94	54.42	47.18
S_6- Control	5.37	4.85		5.11	10.88	13.56		12.22	3.99	4.93		4.46		20.24	23.34	21.79
Mean	10.32	12.58			17.45	25.16			5.14	6.93				32.91	44.67	
	M	S	M x S	S x M	M	S	M x S	S x M	M	S	M x S	S x M		M	S	M x S	S x M
SEd	0.22	0.22	0.36	0.31	0.02	0.44	0.57	0.63	0.04	0.13	0.17	0.18		0.23	0.47	0.65	0.66
CD (p=0.05)	0.95	0.46	1.05	0.64	0.07	0.93	1.19	1.31	0.17	0.27	0.38	0.38		0.98	0.98	1.53	1.39

Table 6: Effect of nitrogen levels and herbicides on K uptake (kg/ha) in finger millet parts at harvest

Treatments (Main plots-M ; Sub plots – S)	Grain				Straw				Root					Total		
	M_1	M_2		Mean	M_1	M_2		Mean	M_1	M_2		Mean		M_1	M_2	Mean
S_1- Pendimethalin	10.90	11.66		11.28	46.06	62.75		54.41	5.62	7.76		6.74		62.58	82.17	72.38
S_2- Oxyfluorfen	11.03	12.77		11.90	58.00	74.90		66.45	6.72	7.34		7.09		75.75	95.01	85.44
S_3- Bispyribac-sodium	10.66	12.15		11.41	66.81	73.53		70.17	7.82	8.73		8.50		85.29	94.41	90.08
S_4- S_1+bispyribac-sodium	12.51	13.63		13.07	73.80	79.29		76.54	6.81	11.28		8.91		93.12	104.2	98.52
S_5- S_2+bispyribac sodium	12.69	14.81		13.75	80.29	86.87		83.58	7.59	11.03		9.24		100.57	112.71	106.57
S_6- Control	5.80	5.50		5.65	43.50	58.12		50.81	5.37	7.03		6.17		54.67	70.65	62.66
Mean	10.60	11.75			61.41	72.57			6.63	8.89				78.66	93.19	
	M	S	M x S	S x M	M	S	M x S	S x M	M	S	M x S	S x M		M	S	M x S	S x M
SEd	0.26	0.21	0.37	0.29	0.35	1.49	1.96	2.11	0.08	0.14	0.20	0.20		0.62	1.49	2.03	2.12
CD (p=0.05)	1.11	0.43	1.17	0.61	1.51	3.11	4.23	4.41	0.33	0.30	0.48	0.42		2.67	3.12	4.65	4.41





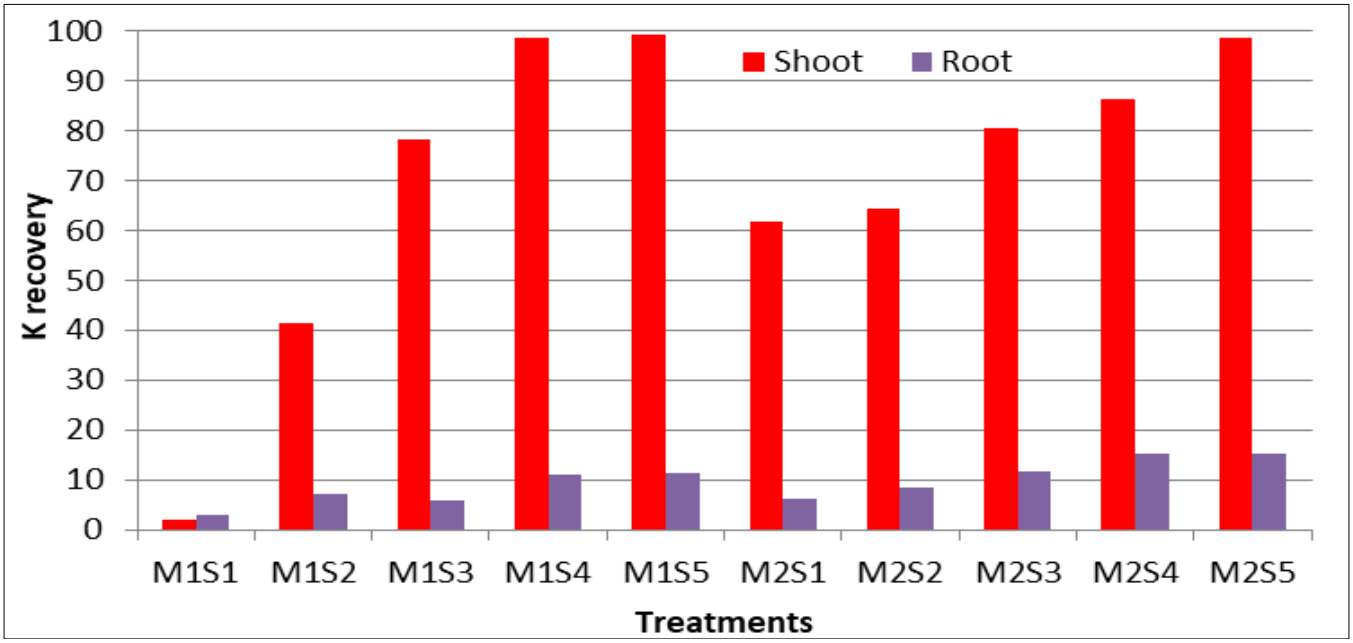
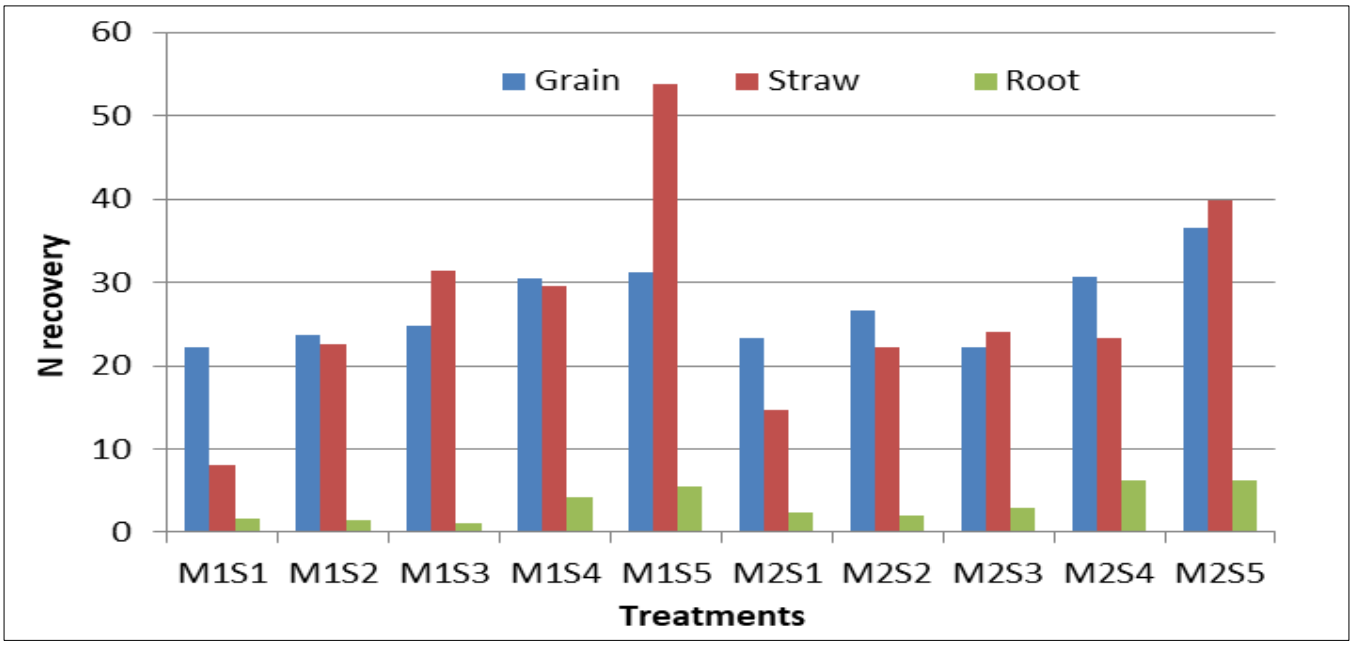


Fig 1: Nutrient Recovery by finger millet parts as influenced by N levels and herbicides interaction during flowering stage



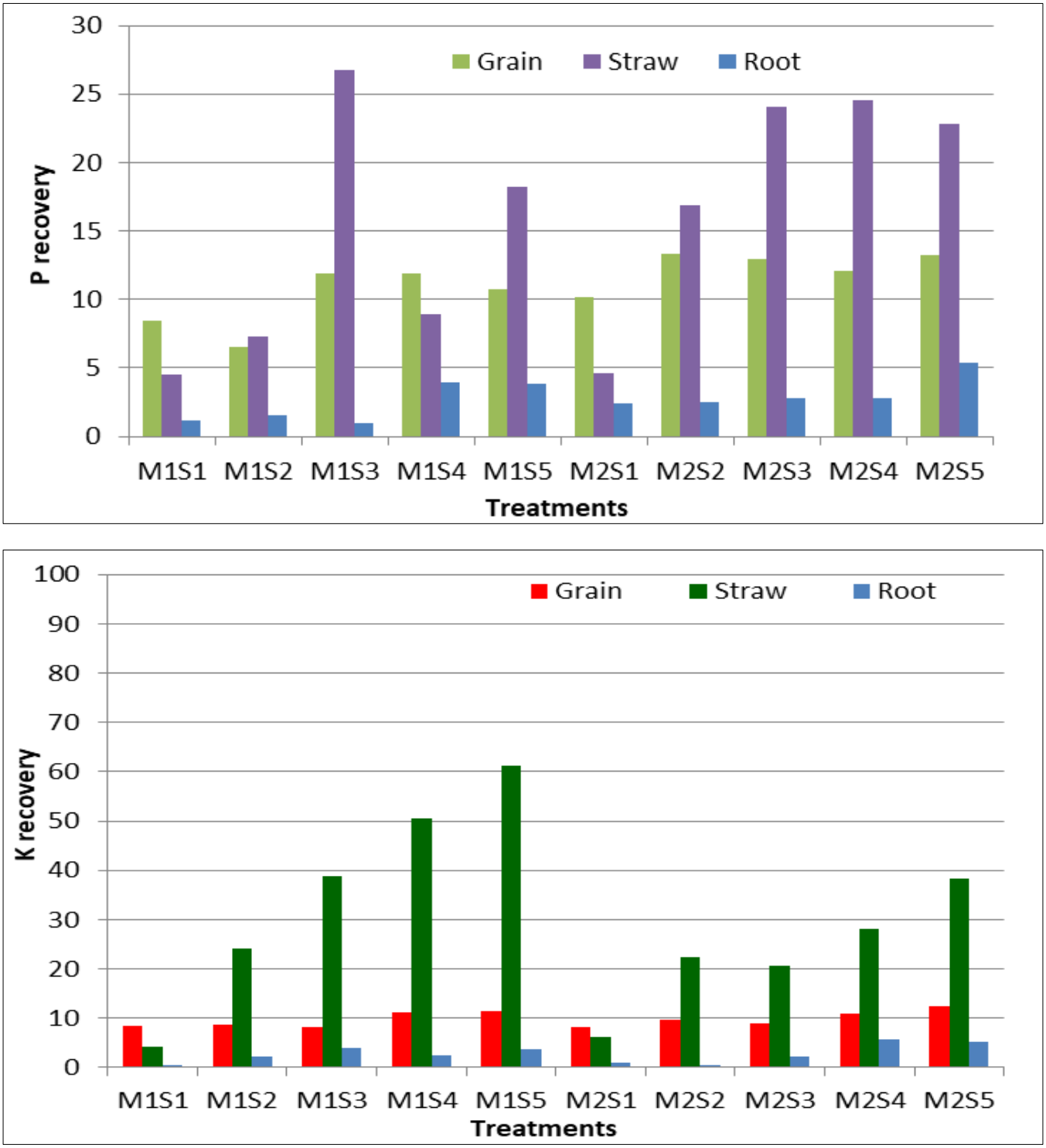


Fig 2: Nutrient Recovery by finger millet parts as influenced by N levels and herbicides interaction during Harvesting stage

Conclusion

From this study, it could be concluded that the application of 125% N along with PE oxyfluorfen 50 g/ha+ EPOE bispyribac sodium 25 g/ha improves the NPK uptake and nutrient recovery efficiency during flowering and harvesting stages of finger millet in sodic soil.

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