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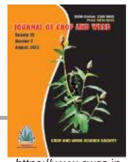

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Impact of weed management on yield, uptake and availability of nutrients in direct sown ragi

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ABSTRACT

A field experiment was laid out during summer season 2021 to assess the impact of weed management on yield, availability of nutrients, uptake by crop and nutrient removal by the weeds in direct sown ragi. The experiment was conducted at the research farm attached to Coconut Research Station, Balaramapuram, Kerala Agricultural University, Thiruvananthapuram, Kerala in RBD with 12 treatments each with three replications. Weed management enhanced the uptake of major nutrients (N, P and K) by ragi to a tune of 43.0-108.0 per cent, 3.2-17.0 per cent, 10.59-121.22 per cent, respectively compared to control (un-weeded check). At 60 DAS, weed management reduced the N removal of weeds by 29.2-93.7 per cent, P removal by weeds 40.3-77.15 per cent and K removal by weeds 4.0-92.6 per cent.Yield enhancement due to weed management practices was 16.3-116.8 per cent over weedy check. Pre-emergence pyrazosulfuron 20 g ha^{-1}followed by wheel hoe weeding at 25 DAS registered the highest grain yield (2072 Kg ha^{-1}) of ragi.

***Keywords*:** Bensulfuron methyl +pretilachlor, Nutrient availability, Nutrient uptake, Oxyfluorfen, Pyrazosulfuron ethyl.

Weed infestation is the serious biotic constraint in finger millet due to its slower initial growth and narrow leaf canopy in the early growth stages. Only when it reaches the mid-growth phase, ragi achieve sufficient canopy cover to shade and restrict the weed growth (Mishra *et al*., 2015). This has led to higher competition for resources in the early growth phase and ultimately led to substantial yield reduction, decline in quality and higher production cost. Planting in wider rows also exacerbated the weed problem in finger millet.

Broad casting and direct drill seeding are the common crop establishment methods prevalent in India, owing to less labour requirement. Whereas crop competitive ability was found to be higher in transplanted crop, since transplanting ensures optimum plant population to suppress the weeds. Prudhvi *et al.* (2020) reported that weed problem was comparatively greater in drilled or broadcasted crops under dry land conditions than transplanted irrigated crops. Higher weed competition during the early growth stages results in heavy yield loss. Uncontrolled weed growth in direct seeded finger millet caused drastic yield reduction of 72.3 per cent (Yathisha *et al*., 2020). The presence of weeds reduces yield and serves as an alternate host for pest and diseases and affects the quality of grain. Shanmugapackiam and Raguchander (2018) reported that in ragi, weed management plays a key role in managing the blast disease, because the weeds *Pennisetum cenchroides* Rich, *Pennisetum purpureum* Schumach., and *Cynodon dactylon* L., served as the source of inoculum for the pathogen *Magnaporthe grisea*.

Finger millet was mostly grown in drylands, having low soil fertility and hence, the competition between crop and weed for nutrients was more severe. Kumar *et al.* (2015a) observed that, weeds removed 49.1 Kg N, 14.0 Kg P, and 32.7 Kg K ha^{-1} from direct sown ragi. Reduction in the density and biomass of weeds favoured the crop growth by enhancing the nutrient uptake in ragi. Weed management resulted in drastic reduction in the removal of nutrients by weeds compared to un-weeded control (Varnekar *et al.*, 2019a). Gowda *et al.* (2012) pointed out that, in ragi, the least amount of nutrient removal by weeds (N, P, K, Mg, Ca and S removal of 9.95, 1.08, 4.94, 2.99, 3.65, and 1.74 Kg ha^{-1}, respectively) were observed in hand weeding treatment. In wet seeded rice, Penox+ cyhalo135 at 15 DAS resulted in the lowest NPK removal by weeds (Raj and Syriac, 2017). In drill sown ragi, PE bensul + preti (10 kg ha^{-1}) recorded higher uptake of NPK (72.5 N, 16.1 P and 56.7 Kg K ha^{-1}) (Kumar *et al.*, 2015b). In finger millet, higher NPK uptake and nutrient recovery at flowering and harvest were observed in the treatment, 125 per cent N along with PE oxyflu$_{50}$ *fb* early post-emergence (EPOE) bispyri25 (Pavitra *et al*., 2019). Due to lesser competition for the nutrients, space and light, PE bensulf+ preti600*fb* EPOE bispyri25 led to higher grain yield (3560 Kg ha^{-1}) and straw yield (6617 Kg ha^{-1}) in ragi (Shanmugapriya, 2019).

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Efficient management of weeds are more important, or else the weeds would utilize the soil- applied fertilizers better than the crops.

Mechanical and manual weeding are commonly adopted by the farmers of India. Though effective, both the methods are labour intensive, time consuming and costlier. Further unfavourable weather conditions and dearth of labours at the right time limit its effectiveness. consequently, herbicidal management of weeds received attention among the farmers. Herbicides are considered to be the cheapest viable option that ensures timely management of weeds in ragi. Dependence on chemical method alone is also not suitable due to the herbicide resistance problem in weeds and weed shift. The most appropriate method for the management of weeds is the integration of herbicides with other non-chemical methods. In this context the present experiment is undertaken to assess the impact of weed management on organic carbon content, N, P and K availability in the soil and uptake of major nutrients (N, P and K) by ragi,removal of major nutrients (N, P and K) by weeds and grain yield of ragi.

MATERIALS AND METHODS

Field experiment was carried out at Kerala Agricultural University, Coconut Research Station, Balaramapuram, Thiruvananthapuram during summer season of 2021 which was located at a North latitude of 8° 22′ 52′′ and East longitude of 77° 1′ 47′′ situated 9 m above MSL. Randomized block design was adopted for the study with 12 treatments and replicated thrice. Details of the treatments with their abbreviations are presented in Table 1.

Table 1: Details of the treatments

Treatments	Treatment details with their abbreviations
T_1	Pre-emergence (PE) bensulfuron methyl + pretilachlor 495 g ha^{-1} (bensul+ preti$_{495}$) 0 DAS *fb* Wheel hoe weeding (WHW) at 25 DAS
T_2	PE bensul+ preti$_{495}$ 0 DAS *fb* bispyribac sodium 20 g ha^{-1}(bispyri$_{20}$) at 25 DAS
T_3	PE bensul + preti$_{495}$0 DAS *fb* penoxsulam+ cyhalofop butyl 125 g ha^{-1}(penox+ cyhalo$_{125}$) at 25 DAS
T_4	PE pyrazosulfuron ethyl (pyrazo$_{20}$) 0 DAS *fb* WHW at 25 DAS
T_5	PE pyrazo$_{20}$ 0 DAS *fb* bispyri$_{20}$ at 25 DAS
T_6	PE pyrazo$_{20}$ 0 DAS *fb* penox+ cyhalo$_{125}$ at 25 DAS
T_7	PE oxyfluorfen 50 g ha^{-1} (oxyflu$_{50}$) 0 DAS *fb* WHW at 25 DAS
T_8	PE oxyflu$_{50}$ 0 DAS *fb* bispyri$_{20}$ at 25 DAS
T_9	PE oxyflu$_{50}$ 0 DAS *fb* penox+ cyhalo$_{125}$at 25 DAS
T_{10}	Wheel hoe weeding (WHW) at 15 and 30 DAS
T_{11}	Hand weeding (HW) at 15 and 30 DAS
T_{12}	Un-weeded control

The textural class of the experimental field was sandy loam, acidic in reaction. The organic carbon content of the soil was 0.25%, available N 275.96 Kg ha^{-1}, available P_2O_5 17.23 Kg ha^{-1} and available K_2O 324.8 Kg ha^{-1}. The climate prevailed in the experimental site was warm humid. The rainfall received during the experimental period was 129.8 mm and 35.02°C was the maximum temperature and 23.08°C was the minimum temperature recorded.

Vakula (PPR 2700), a high yielding leaf blast resistant variety with a duration of 105-110 days released from Agricultural Research Station, Perumalapalli, Andhra Pradesh was used as the test crop. The crop was grown in the inter-row spaces of 60 years old coconut plantation spaced at 7.6 m x 7.6 m with 70 per cent light transmission. The inter-row spaces of coconut were previously utilized for banana cultivation. The entire experimental site was laid out into 36 treatment plots, each having a gross plot of 4.25 m x 3 m. Bunds of 30 cm width and height were taken around the treatment plots. FYM was applied @ 5 tha^{-1}. Using seed drill, seeds were drilled at a row to row spacing of 25 cm and plant to plant spacing of 15 cm adopting a seed rate of 5 Kg ha^{-1}. Crop was fertilized with NPK @ 45: 22.5: 22.5 Kgha^{-1}(KAU, 2016). Nitrogen was given in two split doses (basally and at 21 DAS). Entire dose of P_2O_5 and K_2O were applied at the time of sowing. To prevent overcrowding, thinning was done at 15 DAS and retained one plant per hill. Gap filling was done on the same day in the vacant spaces. Irrigation was given at weekly interval. Spray fluid used was 500 L ha^{-1}. Pre-emergence herbicides were applied with 12 L capacity knapsack sprayer fitted with flat fan nozzle and crop protective herbicide applicator was used to apply the post emergence herbicides.

From the experimental area, composite soil samples were drawn before the start of the experiment. After the harvest of ragi, composite samples were drawn from each treatment plot for the analysis of organic carbon, available N, P_2O_5, and K_2O.

Standard procedures were adopted for the determination of OC, available N, P_2O_5 and K_2O. Grain and straw at harvest and weed samples at 20, 40, and 60 DAS were subjected to acid digestion for the determination of total N, P, and K content using standard procedures. NPK uptake by grain, straw and weed were calculated by multiplying the nutrient contents with its dry matter production. Total NPK uptake by ragi was worked out by adding the respective uptake by straw and grain and expressed as kg ha^{-1}.

Net plot area was harvested treatment-wise. Grains were threshed, winnowed, and dried under the sun and expressed in Kg ha^{-1}. Statistical analysis of the data was carried out using the analysis of variance technique for RBD (Cochran and Cox, 1965) and the significance was tested using F test. The critical difference (CD) was calculated at five per cent probability level wherever the F value was found significant. Pearson correlation analysis was also carried out to test the correlation between grain yield and NPK uptake by ragi and nutrient removal by weeds using grapes Agri 1 package in R (Gopinath *et al.*, 2020).

RESULTS AND DISCUSSION

Nutrient Availability

In general, the data on post-harvest nutrient status revealed that, status of major nutrients (NPK) were lower than that of the initial sample. This was mainly due to the nutrient removal both by crop and weed. The highest availability of soil N (238.2 kg ha^{-1}) was noted in PE preti + $bensul_{495}$ *fb* WHW and was statistically comparable with the treatments PE $pyrazo_{20}$ *fb* WHW, PE preti + bensul $_{495}$ *fb* penox+ $cyhalo_{125}$, WHW at 15 and 30 DAS, HW at 15 and 30 DAS, and PE oxyflu50 *fb* $bispyri_{20}$Whereas, the highest P_2O_5 status was recorded in PE preti + $bensul_{495}$*fb* penox+ $cyhalo_{125}$ (T_3) (24.3kg ha^{-1}) which was on a par with PE $oxyflu_{50}$ *fb* penox+ $cyhalo_{125}$. The treatment PE pyrazo $_{20}$ *fb* WHW recorded the highest available K_2O and it was comparable with PE $pyrazo_{20}$ *fb* penox+ $cyhalo_{125}$, PE $oxyflu_{50}$ *fb* $bispyri_{20}$, PE $oxyflu_{50}$ *fb* WHW, WHW at 15 and 30 DAS,PE $oxyflu_{50}$*fb* penox+ $cyhalo_{125}$ and PE preti + $bensul_{495}$ *fb* penox+ $cyhalo_{125}$. Weed management registered higher values for available N, P_2O_5, and K_2O in post-harvest soil than that of weedy check (Fig. 1) which might be due to significant reduction in the removal of major nutrients (NPK) by weeds as a result of better weed suppression. Brar and WalIa (2007) and Brar *et al.* (2019) reported lesser nutrient uptake by weeds in weed management treatments. The present findings were in concordance with the observations of Singh *et al.* (2017), having higher availability of major nutrients in weed management treatments compared to un-weeded control in wheat.NPK Uptake by Ragi

Weed management significantly influenced the uptake of major nutrients (NPK) by ragi (Table 2). Due to weed management improvement in N uptake was in the range of 43.0 -108.0 per cent, P uptake in the range of 3.2-17.0 per cent and K uptake in the range of 10.6-121.2 per cent, respectively compared to un-weeded control. The enhancement in uptake of major nutrients observed were due to notable reduction in weed biomass and weed density. Better management of weeds provided a competition free environment for crop growth. It was found that NPK uptake by crop was directly linked with the nutrient content and dry matter production (DMP). Higher NPK uptake observed in weed management treatments was because of higher DMP and highercontents of NPK. The result was in consonance with the results of Pandey *et al.* (2006) in wheat.

Amongst treatments, weedy check recorded significantly lower nutrient uptake by ragi compared to weed management treatments. Weed management resulted in substantial increase in the uptake of major nutrients (NPK) by crop compared to control in upland rice (Chakraborti *et al.*, 2017). In weedy check, plant growth was severely affected because of greater competition by weeds throughout the crop growth period which illustrated lower NPK uptake by crop.

Higher uptake of N was noted in PE $pyrazo_{20}$ *fb* WHW and it was on par with PE $pyrazo_{20}$ *fb* penox+ $cyhalo_{125}$. Whereas, the highest total P uptake was recorded in WHW at 15 and 30 DAS and it was statistically comparable with PE $oxyflu_{50}$ *fb* penox+ $cyhalo_{125}$. Similar to N uptake, the highest uptake of K was also recorded in PE $pyrazo_{20}$ *fb* WHW which was comparable with PE $pyrazo_{20}$ 0 DAS *fb* penox+ $cyhalo_{125}$, WHW at 15 and 30 DAS, and PE pyrazo20 0 DAS *fb* bispyri20 at 25 DAS. This was because of significant reduction in the biomass of weed and higher WCE, which resulted in a competition free environment for the availability of nutrients, space and moisture. Sunil *et al*. (2011) also made similar conclusion that weed management resulted in significant enhancement in the uptake of major nutrients. Increase in NPK uptake observed in PE pyrazo20*fb* WHW, PE $pyrazo_{20}$ *fb* penox+ $cyhalo_{125}$, WHW at 15 and 30 DAS and PE $pyrazo_{20}$ *fb* $bispyri_{20}$ were mainly attributed to better availability of nutrients resulting from the reduction in the nutrient removal by weeds (Table 3). The study also revealed that NPK uptake by ragi was positively correlated with grain yield of ragi (Fig. 3). Sharma and Singh (2011) observed that mechanical weeding at 15 and 30 DAS resulted in significant improvement in uptake of major nutrients (NPK) by wheat.

Table 2: Effect of weed management on nutrient uptake by ragi at harvest

Treatments	N uptake (Kg ha^{-1})			P uptake (Kg ha^{-1})			K uptake (Kg ha^{-1})		
	Straw	Grain	Total uptake	Straw	Grain	Total P uptake	Straw	Grain	Total uptake
T_1	30.52	17.00	47.52	10.91	11.95	22.86	39.41	7.16	46.57
T_2	32.99	14.25	47.24	10.86	11.98	22.84	38.99	6.99	45.99
T_3	28.89	16.74	45.64	11.00	12.14	23.14	37.21	6.50	43.71
T_4	33.77	32.10	65.87	10.96	13.00	23.96	59.05	7.98	67.03
T_5	35.47	22.32	57.79	11.84	12.41	24.25	57.79	5.65	63.44
T_6	36.20	24.87	61.07	10.86	13.32	24.18	56.27	10.03	66.30
T_7	32.57	12.73	45.30	11.49	10.76	22.25	34.48	7.64	42.12
T_8	29.73	15.89	45.62	11.88	12.20	24.08	28.65	4.86	33.51
T_9	32.89	12.74	45.63	13.50	11.21	24.71	34.39	8.16	42.55
T_{10}	32.55	21.29	53.84	13.44	11.78	25.22	57.64	8.29	65.93
T_{11}	33.34	16.07	49.39	10.73	12.80	23.53	28.39	6.67	35.06
T_{12}	24.71	6.96	31.67	11.05	10.49	21.55	25.41	4.89	30.30
LSD (0.05)	**5.604**	**2.471**	**6.348**	**0.386**	**0.347**	**0.532**	**9.424**	**1.570**	**7.361**

Table 3: Effect of weed management on nutrient removal by weeds in ragi

Treatments	N removal by weeds (Kg ha^{-1})			P removal by weeds (Kg ha^{-1})				K removal by weeds (Kg ha^{-1})		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS		20 DAS	40 DAS	60 DAS
T_1	1.98	2.93	20.93	0.11	0.28	1.32	(0.76)	2.44	2.37	9.15
T_2	0.81	5.05	49.73	0.03	0.49	2.64	(5.97)	0.49	3.60	36.23
T_3	2.72	3.93	61.19	0.20	0.39	1.44	(1.07)	3.20	3.67	28.58
T_4	0.94	0.48	10.24	0.02	0.06	1.01	(0.02)	0.78	0.35	4.53
T_5	1.73	1.16	14.89	0.13	0.12	1.70	(1.90)	1.70	0.90	7.74
T_6	0.76	0.35	12.55	0.01	0.06	1.41	(0.98)	0.90	0.32	7.72
T_7	1.06	0.54	32.90	0.06	0.08	1.50	(1.26)	0.85	0.38	17.94
T_8	0.43	1.35	53.15	0.07	0.11	2.30	(4.32)	0.27	0.93	27.70
T_9	0.45	2.31	44.94	0.01	0.25	2.02	(3.07)	0.21	1.63	24.33
T_{10}	0.82	1.10	8.72	0.05	0.08	1.15	(0.32)	0.81	0.65	6.15
T_{11}	1.91	0.23	98.40	0.09	0.04	1.73	(1.99)	1.58	0.24	58.83
T_{12}	5.36	33.53	138.99	0.61	3.16	4.42	(18.66)	5.21	23.20	61.25
LSD (0.05)	0.252	0.962	6.250	0.023	0.093	0.247		0.257	0.587	2.471

DAS- Days after sowing, original values are presented in the parentheses, values on P removal by weeds are subjected to square root transformation

Among the herbicide treatments, pyrazo$_{30}$ resulted in significantly higher nutrient uptake by rice (Gowda *et al.,* 2009). Raj and Syriac (2015) pointed out that penox + cyhalo135 or 130 at 15 DAS resulted in higher NPK uptake by rice.

Nutrient removal by weeds

Weed management profoundly influenced the removal of major nutrients (NPK) by weeds at 20, 40 and 60 DAS (Table 3). Weeds usually grow vigorously and draw available nutrients from the soil at a faster rate compared to that of associated crop and caused nutrient deficiency in crop plants (Gaurav *et al.,* 2018). It was clearly evident from correlation data that NPK uptake by weeds at 40 and 60 DAS, had a negative correlation with grain yield (Fig. 4).

Weed management remarkably reduced the nutrient removal by weeds (Table 3). At 40 DAS, reduction in N removal by weeds was in the range of 84.9-99.3 per cent, P removal in the range of 84.5-98.7 per cent, and K removal in the range of 84.2-99.0 per cent, respectively. However, at 60 DAS, N removal was in the range of 29.2-93.7 per cent, P in the range of 40.3-77.2 per cent and K in the range of 4.0-92.6 per cent, respectively.

At 20 DAS, the treatments, PE oxyflu$_{50}$*fb* bispyri$_{20}$(T_8), PE pyrazo$_{20}$*fb* penox+ cyhalo$_{125}$(T_6), and PE oxyflu$_{50}$*fb* penox+ cyhalo$_{125}$(T_9) resulted in significant reduction in the removal of major nutrients (NPK). Whereas at 40 DAS, treatment HW at 15 and

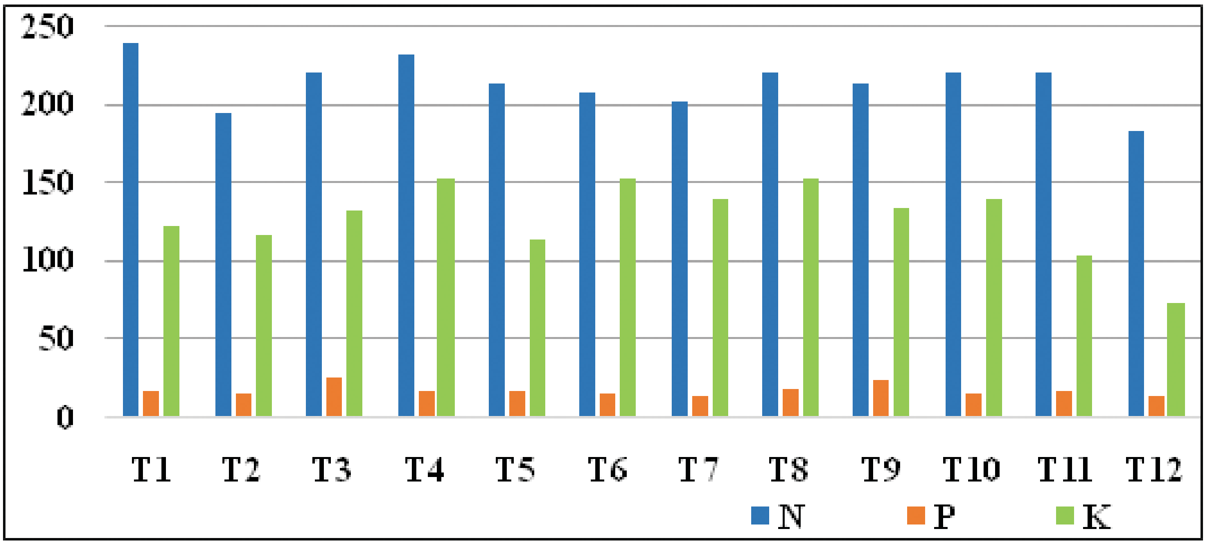

Fig. 1: Effect of weed management on NPK status of post-harvest soil, Kg ha^{-1}

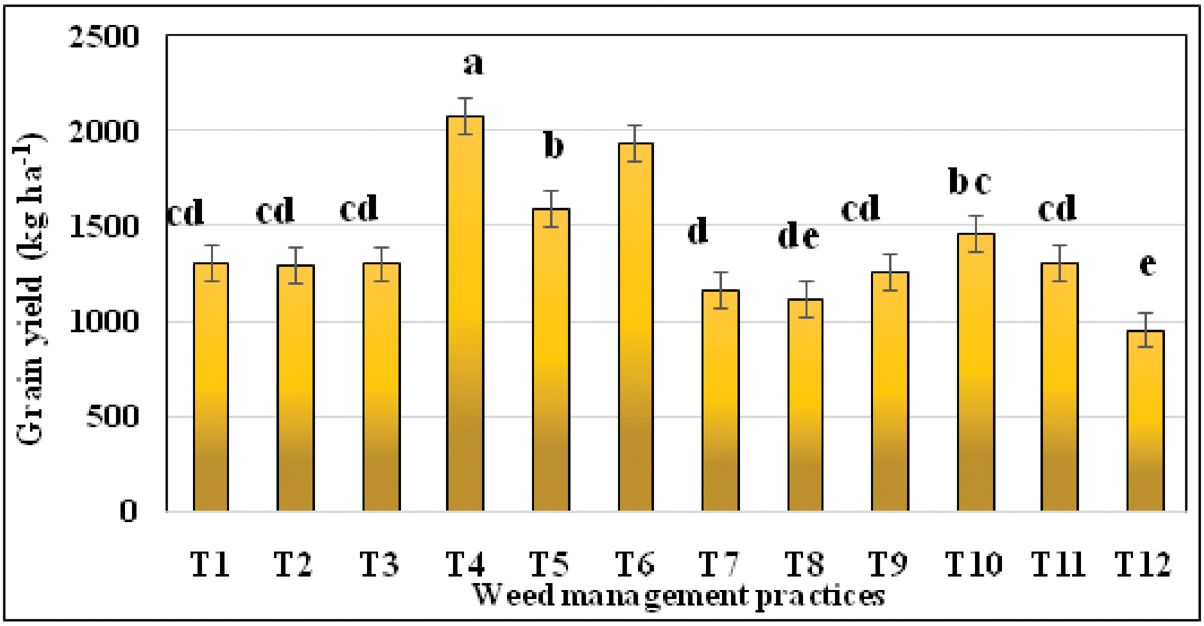

Fig. 2: Effect of weed management on grain yield of ragi

30 DAS (T11) recorded the lowestremoval of major nutrients (NPK) and at 60 DAS, treatment WHW at 15 and 30 DAS (T10) resulted in the lowest removal of N and PE pyrazo $_{20}$ *fb* WHW (T4) recorded the lowest removal of P and K. Lesser dry matter accumulation and nutrient content in weeds resulting from better management of weeds due to PE application of herbicides and HW/WHW/ POE of penox + cyhalo125. The result was in line with the findings of Ghosh *et al.* (2020), who observed that nutrient removal by weeds was directly related to weed biomass and nutrient content. It was also reported that removal of nutrients was significantly reduced by weed management. Thalla and Jena (2014) revealed that, PE pyrazo20, cono weeding and HW registered the lowest removal of NPK by weeds. Reddy and Ameena (2021) also made similar observations that PE pyrazo25*fb* HW at 40 DAS and POE bispyri25*fb* HW at 40 DAS resulted in drastic reduction in the nutrient removal by weeds compared to un-weeded control. Raj and Syriac (2017) also reported the lowest nutrient uptake by weeds due to POE penox + cyhalo135 in wet seeded rice.

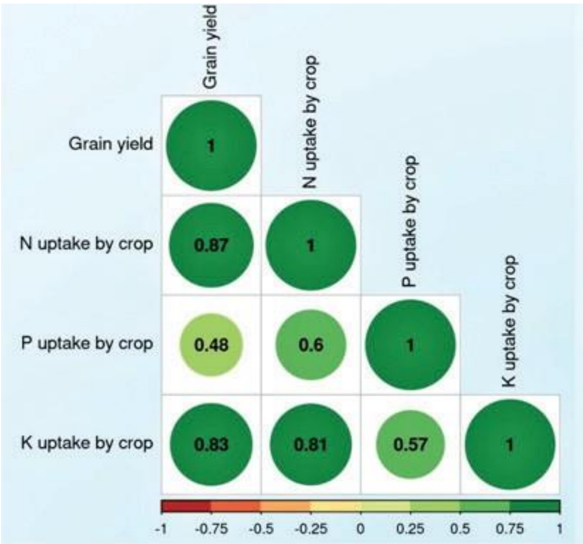

Fig. 3: Correlation between nutrient uptake by crop and yield

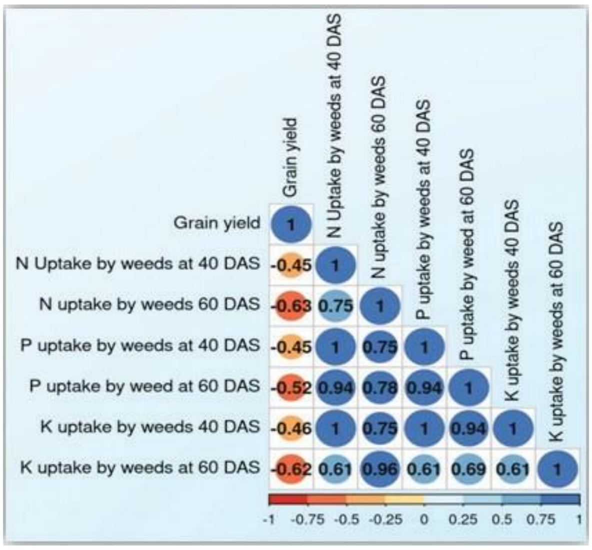

Fig. 4: Correlation between nutrient uptake by weed and grain yield

Present study also revealed a negative correlation between yield and nutrient uptake by weeds (Fig. 4).

In comparison with other weed management treatments, weedy check resulted in higher nutrient removal by weeds at all the observation stages due to uncontrolled weed growth. Uncontrolled weed growth depleted the soil available nutrients and moisture present in the soil and adversely affected the DMP in weedy check. Higher dry matter accumulation in weeds was the reason for higher NPK removal in control (T_{12}) (Table 3). Similar observations were also made by Varnekar *et al.* (2019b) in finger millet and Ramesh *et al.* (2019) in pearl millet. Weedy check registered higher NPK uptake by weeds compared to herbicidal treatmentsin rice (Nazir *et al.*,2022).

Grain yield

Weed management had significant influence on grain yield of finger millet. Compared to weedy check (control) the yield enhancement noted in weed management treatments were in the range of 16.3-116.8 per cent. Pre-emergence pyrazo$_{20}$*fb* WHW (T_4) resulted in the highest grain yield (2072 Kg ha^{-1}) which was comparable with PE pyrazo$_{20}$*fb* penox+ cyhalo$_{125}$(T_6). Pre-emergence pyrazo$_{20}$*fb* WHW or POE penox + cyhalo$_{135}$ resulted in better control of weeds, which would reduce the competition for nutrients during the critical periods of crop growth. Reduction in density and weed biomass and subsequent decline in nutrientdrain by*weeds improved the availability of nutrients and uptake by the crop. Pallavi *et al.* (2017) reported that higher uptake of nutrients increased the photosynthetic activity eventually resulted in the production of higher paniclesm^{-2}, fingers per ear head, and ear head weight. Pre-emergence pyraz$_{15}$ resulted in lesser weed density and biomass and higher grain yield in ragi (Ramadevi *et al.*, 2021). Pal *et.al.* (2012) observed that PEpyrazo$_{42}$ at 3 DAT, resulted in higher yield in rice. Pre-emergence preti+ bensul*fb* inter cultivation resulted in higher yield compared to PE preti+ bensulalone (Satish *et al.*, 2018). Post emergence penox + cyhalo$_{125, 130 \text{ or } 135}$ resulted in higher grain yield in rice (Raj and Syriac, 2015). Unchecked weed growth led to severe competition between crop and weed resulting in lower yield in weedy check. Yathisha *et al.* (2020) pointed out that unchecked weed growth resulted in 71 per cent yield reduction in direct seeded finger millet.

CONCLUSION

It could be concluded that weed management had remarkable influence on the availability of nutrients, NPK uptake by crop, nutrient removal by weeds and grain yield in ragi. Grain yield of ragi can considerably be increased by bringing down the nutrient loss through proper weed management. Application of PE pyrazosulfuron 20 g ha^{-1}*fb* WHW at 25 DAS was the best proposition for achieving highest grain yield and uptake of NPK by finger millet and the lowest NPK removal by weeds.

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