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Response of Foliar Nutrient Management on Yield, Nutrient Uptake and Use Efficiency of *Utera* Rapeseed-Mustard Varieties Grown in Rice–Fallows of Lower Indo-Gangetic Plains

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ABSTRACT

A two-year field experiment during winter seasons (November to February) of 2020–2021 and 2021–2022 was conducted to evaluate the effect of foliar spray of macro and micro nutrients on different rapeseed-mustard varieties under relay cropping in rice fallows. The results revealed that foliar spray of macro and micro nutrients had significant effect on seed yield, oil content, oil yield, nutrient uptake and use efficiency irrespective of rapeseed mustard varieties. Variety *Binoy* (B-9) registered significantly higher oil content (38.1%) over other two varieties but PM 28 showed its superiority when total oil yield per unit area was considered. Mustard variety PM 28 exhibited significantly higher total nitrogen (48.78 kg ha^{-1}), phosphorus (11.79 kg ha^{-1}), potassium (45.97 kg ha^{-1}) and sulphur (23.29 kg ha^{-1}) uptake both in seeds as well as in stover. Combined application of macro and micro nutrients *i.e.*, spraying of N:P:K (19:19:19) @ 2% twice at 30 DAS and 45 DAS+$ZnSO_4$@ 0.05% at 40 DAS+Boron (20%) @ 0.1% at 50 DAS exhibited significantly higher seed yield, oil content, protein content, nutrient uptake of N, P, K, S, Zn and nitrogen use efficiency than other foliar spray of nutrients. Rapeseed-mustard variety PM-28 along with foliar application of N:P:K (19:19:19) @ 2% twice at 30 DAS and 45 DAS+$ZnSO_4$@ 0.05% at 40 DAS+Boron (20%) @ 0.1% at 50 DAS performed best in rice fallow of lower Indo-Gangetic plains.

KEYWORDS: NUE, nutrient uptake, oil yield, spray nutrients

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1. INTRODUCTION

The Indo-Gangetic plain (IGP) of India, spread over 44 million ha, is the food basket of South Asia. Approximately 76% of its area falls in India, dominated by Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal (Kumar et al., 2021). The IGP regions of eastern India comprises alluvial soil, predominant with rice-based cropping systems which are prevailing years after years with locally available (Midya et al., 2021) long duration rice cultivars. This triggers delayed sowing of subsequent crops resulting poor yield. A sustainable production is needed to balance world's nutritional needs while reducing agriculture's negative environmental impact (Liu et al., 2022). Adopting conservation or sustainable farming, *utera* rapeseed-mustard can easily be raised effectively and efficiently just after *aman* paddy. It might have emphasized to adapt in large scale for increasing cropping intensity in Eastern India (Kumar et al., 2019). In spite of advantageous role of tillage, conservation agriculture is getting impetus of having benefits of undisturbed soil (Ramesh et al., 2021). *Utera* cropping minimizes tillage cost and taking advantages of residual fertility and moisture (Venkateswarlu et al., 2009). Crop varieties efficient in extracting nutrients from soil for growth are the cornerstone for future global crop production (Lyzenga et al., 2023). Apart from sowing time, varieties plays a crucial role to realize potential yield of rapeseed-mustard (Sharma and Kumar, 2023, Saha et al., 2023). Adopting smart agronomic tools like foliar spray of nutrients also augment the yield of *utera* rapeseed-mustard (Saha et al., 2023).

Rapeseed-mustard is the leading edible oilseed crop (Kumar et al., 2014) after groundnut, contributing nearly 26.1% of total oilseed production in India (Meena et al., 2018 and Meena et al., 2013). Eight different species are being cultivated all over the globe (Singh et al., 2023). The crop responded well to applied major plant nutrients (N, P and K) along with sulfur, zinc and boron as they plays vital roles in production phenology of crops and show positive response on appliance of sulfur, zinc and boron (Dhaliwal et al., 2021, Karthika et al., 2020, Pati and Mahapatra, 2015). Foliar fertilization is more effective, economical (Fageria et al., 2009) and successful in improving yields by delaying senescence and converting late flushes of flower into economic parts (Banerjee et al., 2019). It can make nutrients available directly to the site of food synthesis with minimum wastage (Saha et al., 2023). Foliar feeding of micronutrients is cheap, more effective, efficient and having lesser impact to pollution as it adds less fertilizers to the environment (Bhatt et al., 2020 and Aziz et al., 2019). Foliar application of nitrogenous fertilizers would not only reduce soil pollution but also improves uptake of nitrogen (Sunkad et al., 2023). Rapeseed-mustard is very sensitive to micronutrient deficiency, especially zinc and boron (Rathore et al., 2015). S (sulfur), Zn, B and Fe are important plant nutrients to optimize productivity of rapeseed-mustard (Meena et al., 2022b). The oil content of rapeseed-mustard is being largely governed by mineral fertilization of the crops (Olama et al., 2014). On the other hand, NPK fertilizers along with micronutrients zinc (Zn) and boron (B) contributes an important role in nutrient uptake and nutrient use efficiency in oilseed crops (Immanuel, 2019). K application can improve nutrient use efficiency (NUE) of other nutrients with a capacity to mitigate adverse effects of excessive N on disease and insect-pest incidences, improving crop yields, crop health and NUE (Perelman et al., 2021).

In this experiment, an attempt was made to study the effect of foliar spray of nutrients on different varieties of rapeseed-mustard with reference to nutrient content and uptake, seed oil content and protein content of the crop.

2. MATERIALS AND METHODS

A field experiment was conducted during winter seasons (November to February) of 2020–21 and 2021–22 at Pulses and Oilseeds Research Station, Berhampore, West Bengal 742101, India with 24° 6' N latitude and 88° 15' E longitude and average altitude of 41 m above mean sea level. The experiment was designed in a splitplot design keeping rapeseed-mustard varieties, viz., V_1=*Anushka,* V_2=*Biney* (B-9) and V_3=PM–28 in main plots and eight different foliar spray of nutrients viz. F_0: No foliar spray, F1: Foliar spray with N:P:K (19:19:19) @ 2% at 30 DAS and 45 DAS, F_2: Foliar spray with $ZnSO_4$ @ 0.5% at 40 DAS, F_3: Foliar spray with Boron (20%) @ 0.1% at 50 DAS, F_4: F_1+F_2, F_5: F_1+F_3, F_6: F_2+F_3, F_7: F_1+F_2+F_3 in sub-plots (Table 1). Each main plots and sub-plots were replicated thrice in the experimental field having plots of size 5×4 m^2. The weather of the experimental site was under sub-tropical climate having average annual rainfall ranging from 1200 to 1300 mm concentrating during rainy months from June to September. During the crop growth period the mean maximum temperature varied between 21.3°C to 35.4°C, and minimum between 10.7°C to 26.5°C. The maximum and minimum relative humidity ranged between 71.4% to 95.4% and 38.6% to 80.1%, respectively.

The soil of the experimental site was silty clay loam in texture, neutral in reaction (pH 7.46), having organic carbon, available nitrogen, phosphate and potash with 0.40%, 299 kg ha^{-1}, 45 kg ha^{-1} and 278 kg ha^{-1} respectively.

The seeds of different varieties of rapeseed-mustard were sown in the standing rice field 10 days before harvesting of rice. Nitrogen, phosphorus and potassium were applied in the form of straight fertilizers i.e. urea,

Table 1: Effect of different varieties and foliar spray of nutrients on seed yield, oil content (%), oil yield (kg ha^{-1}), protein content (%), protein harvest (kg ha^{-1}), PFP (kg kg^{-1}), AE (kg kg^{-1}) and ARE of relay rapeseed-mustard

Treatments	Seed yield (kg ha^{-1})	Oil content (%)	Oil yield (kg ha^{-1})	Protein content (%)	Protein harvest (kg ha^{-1})	PFP (kg kg^{-1})	AE (kg kg^{-1})	ARE
Rapeseed-mustard varieties (V)								
V_1	817.98	37.1	305.5	13.03	108.3	15.59	3.41	0.20
V_2	960.46	38.1	368.2	13.67	132.2	18.29	5.23	0.27
V_3	1198.46	33.5	404.1	16.22	194.7	22.87	5.17	0.27
SEm±	13.09	0.17	3.9	0.07	2.19	0.242	0.31	0.012
CD (p=0.05)	42.70	0.55	12.8	0.27	7.14	0.79	1.00	0.040
Foliar spray of nutrients (F)								
F_0	774.22	31.9	245.0	11.70	93.1	15.48	-	-
F_1	1012.94	35.4	355.2	14.20	145.4	18.57	5.00	0.22
F_2	872.00	36.0	310.1	13.89	121.3	17.44	2.86	0.15
F_3	891.50	35.5	312.3	13.65	122.0	17.83	2.90	0.16
F_4	1076.72	38.0	406.3	15.70	171.4	19.74	6.06	0.34
F_5	1130.06	37.9	425.8	15.11	172.3	20.71	6.84	0.37
F_6	947.72	36.2	340.7	13.83	132.7	18.95	4.23	0.21
F_7	1233.22	38.9	479.0	16.36	202.4	22.60	8.93	0.51
SEm±	25.83	0.43	10.1	0.09	4.11	0.494	0.44	0.017
CD (*p*=0.05)	72.64	1.20	28.3	0.25	11.57	1.389	1.23	0.047
Interaction V×F								
SEm±	44.74	0.738	17.4	0.19	7.126	0.855	0.76	0.029
CD (*p*=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Interaction F×V						0.836	0.77	0.029
SEm±	43.85	0.711	16.8	0.15	7.016	NS	NS	NS
CD (*p*=0.05)	NS	NS	NS	NS	NS			

single super phosphate and muriate of potash at 50% of the recommended dose (100:50:50 kg ha^{-1}) just five days before sowing of rapeseed mustard seeds when soil was saturated with excess moisture. The foliar application was done according to the treatments. Irrigation to each plot was uniformly applied as life savers. Plant protection measures were taken as and when required and seeds were treated with fungicides irrespective of treatments.

The seed samples from each treatment were taken for oil estimation with the help of Soxhlet's apparatus (Anonymous, 1970). The nutrient content of seed and stover (N, P, K, S and Zn content) were estimated in both the years and uptake was calculated with respective nutrient content (Singh et al., 2005). Protein content of the grain was driven out by multiplying the nitrogen content with the multiplication factor 6.25. Further the protein harvest per unit area (kg ha^{-1}) was calculated by multiplying the protein content with seed yield. Partial factor productivity (PFP), agronomic efficiency (AE) and apparent recovery efficiency (ARE) of applied nutrients were calculated using the following formulae suggested by Baligar et al. (2001), Dobermann (2007), Fageria et al. (2008) and Fageria et al. (2015). Standard statistical methods of analysis were followed (Panse and Sukhatme, 1978; Gomez and Gomez, 1984).

3. RESULTS AND DISCUSSION

3.1. Seed yield

A significant difference was found among tested varieties of rapeseed-mustard on seed yield (Table 1). Among three tested varieties the highest seed yield was achieved by PM-28 (1198.46 kg ha^{-1}) which was significantly higher than others. Higher seed yield achieved by PM-28 might be attributed to higher growth and yield attributes, longer duration and higher nutrient uptake than other two varieties. Foliar spray of N:P:K (19:19:19) @ 2% twice at 30 DAS and

45 DAS+$ZnSO_4$ @ 0.05% at 40 DAS+Boron (20%) @ 0.1% at 50 DAS revealed significantly highest seed yield across varieties. Combined application of macro and micro resulted higher seed yield might be due to the synergistic effect. Aziz et al. (2019) also found similar findings of increased tillering, spike length, grain yield in wheat. Foliar fertilizers used in the winter oilseed rape affected an increase in yield on average ranging from 2.5% to 18.5% (Sikorska et al., 2020). Ashkiani et al. (2020) found that application $ZnSO_4$ had a positive effect on rapeseed-mustard seed yield and oil yield. Meena et al. (2022b) confirmed that application of secondary (S) and micronutrients (Zn and B) significantly enhanced yield (28.5 q ha^{-1}) in rapeseed-mustard.

3.2. Oil content and oil yield

Among various test varieties different foliar spray of nutrients significantly influenced the oil content in seed as well as the oil yield irrespective of all three tested varieties. Highest oil content was found in B-9 (38.1%) followed by *Anushka* (37.1%) and PM-28 (33.5%). Among different combinations of foliar spray of nutrients spray of N:P:K (19:19:19) @ 2% twice at 30 DAS and 45 DAS+$ZnSO_4$ @ 0.05% at 40 DAS+Boron (20%) @ 0.1% at 50 DAS showed significantly higher seed oil content (38.9%). The trend was similar in all the three tested varieties (Table 1). Considering the total oil yield mustard variety PM–28 (404.1 kg ha^{-1}) out yielded other two yellow sarson varieties viz. B-9 (368.2 kg ha^{-1}) and *Anushka* (305.5 kg ha^{-1}). Among the different foliar spray of nutrients spray of N:P:K (19:19:19) @ 2% twice at 30 DAS and 45 DAS+$ZnSO_4$ @ 0.05% at 40 DAS+Boron (20%) @ 0.1% at 50 DAS proved its superiority over others (Table 1). Cakmak (2008) found that application of Zn had a significant effect on seed oil content. The application of Zn had a significant effect on rapeseed-mustard oil and oil content of seeds increased with Zn application (Ahmadi, 2010). Application of foliar nutrients might have positive effect for enhancing metabolic and photosynthetic activity due to their involvement in chlorophyll formation, different enzyme activation as well as primary and secondary metabolism, and thus, ultimately increased the oil quantity (Rana et al., 2020). Their findings aligned with findings of Sarkar et al. (2021) were they found that foliar nutrient spray significantly increase the oil percentage (39.9%) in hybrid mustard (Kesari-5111) and lowest oil content (33.7%) was obtained with no foliar spray treatment. Meena et al. (2022b) observed positive effect of nutrient enrichment of FYM with micro (Zn+B) and secondary (S) nutrients for maximizing oil content (43.1%) and seed yield in rapeseed-mustard.

3.3. Protein content and protein yield

The protein content in seed and protein harvest by crop were significantly influenced due to different foliar spray of nutrients and the trends were similar in all the three tested varieties. Highest protein content was found in PM-28 (16.22%) followed by B-9 (13.67%) and *Anushka* (13.03%). Among different combinations of foliar spray of nutrients spray of N:P:K (19:19:19) @ 2% twice at 30 DAS and 45 DAS+$ZnSO_4$ @ 0.05% at 40 DAS+Boron (20%) @ 0.1% at 50 DAS showed significantly higher seed protein content (16.36%). The trend was similar in all the three tested varieties. Considering the total protein yield mustard variety PM-28 (194.7 kg ha^{-1}) gave significantly higher protein yield than other two yellow sarson varieties viz. B-9 (132.2 kg ha^{-1}) and *Anushka* (108.3 kg ha^{-1}). Among the different foliar spray of nutrients spray of N:P:K (19:19:19) @ 2% twice at 30 DAS and 45 DAS+$ZnSO_4$@ 0.05% at 40 DAS+Boron (20%) @ 0.1% at 50 DAS (202.4 kg ha^{-1}) proved its superiority over others (Table 1). The positive effect of balanced nutrients supply of NPK along with S and Zn on seed and quality yield were also reported by Tetarwal et al. (2013). Zinc is directly or indirectly required by several enzyme systems and is closely involved in the nitrogen metabolism which ultimately enhanced the synthesis of many enzymes and proteins in plant body (Mondal et al., 2020). Meena et al. (2022a) in an experiment when they applied 125% RDF of NPK along with S and Zn got higher seed protein yield in *Brassica* (Indian mustard). Conversely, the combined effect of macro and micro nutrients played a very significant role by partitioning of photosynthates due to their synergistic effect (Singh et al., 2020) which also helped in better yielding of seed protein.

3.4. Nutrient uptake

From two years of field experiments a significant difference in nutrient uptake by seeds, stover and total nutrient uptake by rapeseed-mustard were noticed among the tested varieties (Figure 1 to 5). Mustard variety PM 28 showed significantly higher total nitrogen (48.78 kg ha^{-1}), phosphorus (11.79 kg ha^{-1}), potassium (45.97 kg ha^{-1}) and sulphur (23.29 kg ha^{-1}) uptake when compared with other two varieties. Although total zinc uptake was significantly higher in B-9 (116.9 g ha^{-1}). Among different combinations of foliar spray of nutrients, foliar spray of N:P:K (19:19:19) @ 2% twice at 30 DAS and 45 DAS+$ZnSO_4$ @ 0.05% at 40 DAS+Boron (20%) @ 0.1% at 50 DAS exhibited significantly higher total nutrient uptake than other foliar spray of nutrients in different varieties of rapeseed-mustard. No significant interaction was noticed in nutrient uptake of *relay* rapeseed mustard in rice fallows. Ganie et al. (2014) opined that boron nutrition significantly improved the N, P, K, S and B uptake in French bean. Chaudhary et al. (2016) and Meena et al. (2022a) reported, foliar application of nutrients ensured balanced and continuous supply of essential plant nutrients throughout the growth periods. This attributed higher

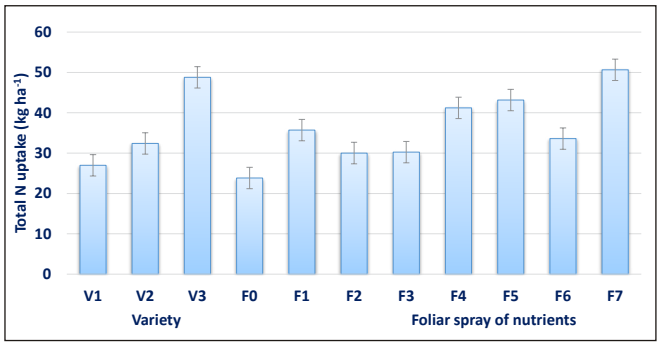

Figure 1: Total N uptake (kg ha^{-1}) by *utera* rapeseed-mustard

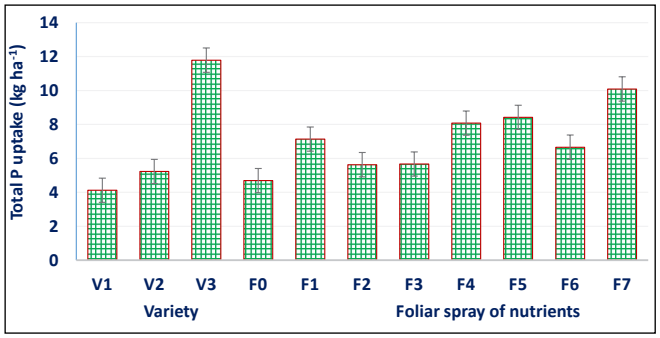

Figure 2: Total P uptake (kg ha^{-1}) by *utera* rapeseed-mustard

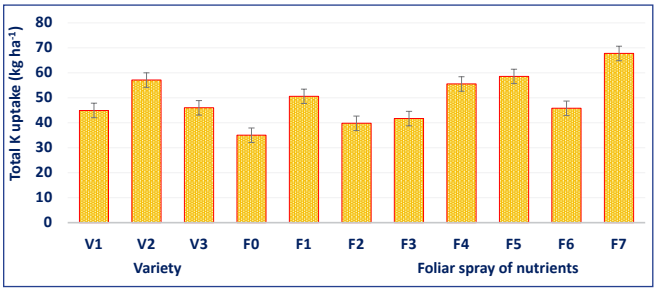

Figure 3: Total K uptake (kg ha^{-1}) by *utera* rapeseed-mustard

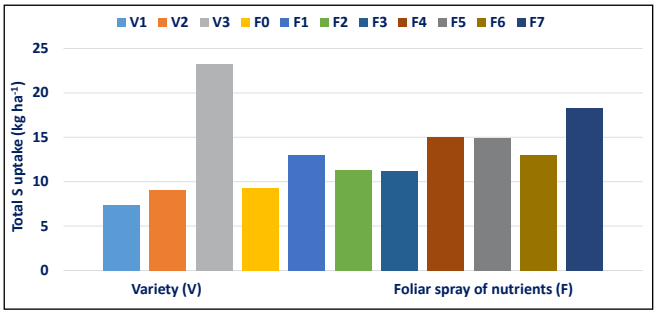

Figure 4: Total S uptake (kg ha^{-1}) by *utera* rapeseed-mustard

uptake of nutrients like N, P, K, S by rapeseed-mustard. Higher accumulation and uptake of nutrients under these treatments could be ascribed to better availability and synergistic effect of applied nutrients (Kumaran and Solaimalai, 2000; Samant and Panigrahi, 2018). Marked enhancement in N, P and K uptake in rapeseed-mustard was due to application of sulfur and boron which attributed to better utilization of nutrients through the

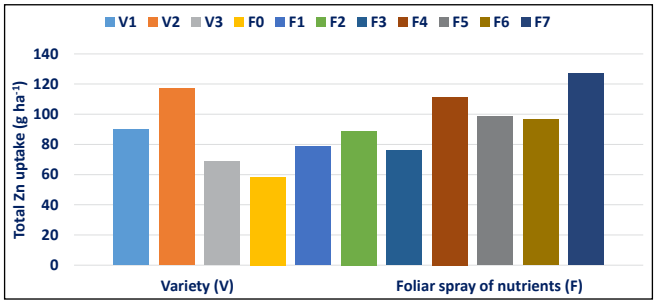

Figure 5: Total Zn uptake (g ha^{-1}) by *utera* rapeseed-mustard

well-developed root system with a concomitant increase in higher yield and higher concentration of N, P and K in both seed and stover (Mathew and George, 2013; Jaiswal et al., 2015; Basumatary et al., 2021).

3.5. Nitrogen use efficiency (NUE)

Among different tested varieties of rapeseed-mustard, PM-28 revealed significantly higher partial factor productivity (22.87 kg kg^{-1}). While assessing the agronomic efficiency, B-9 showed significantly higher value (5.23 kg kg^{-1}) than *Anushka* (3.41 kg kg^{-1}) but at par with PM-28 (5.17 kg kg^{-1}). B-9 and PM–28 showed at par values of Apparent Recovery Efficiency (0.27) but significantly higher than *Anushka* (0.20). Partial Factor Productivity (PFP), Agronomic efficiency (AE) and Apparent Recovery Efficiency (ARE) were significantly influenced by application of different combinations of foliar spray of nutrients significantly higher values were exhibited by the treatment having foliar spray of N:P:K (19:19:19) @ 2% twice at 30 DAS and 45 DAS+$ZnSO_4$ @ 0.05% at 40 DAS+Boron (20%) @ 0.1% at 50 DAS over rest of the treatments on pooled data basis (22.60 kg kg^{-1} 8.93 kg kg^{-1} and 0.51, respectively, Table 1). High nutrient efficient cultivars facilitated a production system with sustainability as reported by Adhikari et al. (2023). By applying foliar spray of essential micronutrients like Zn and B along with NPK fertilizers, Immanuel (2019) succeeded to boost and sustain seed yield of sunflower through increasing nutrient uptake and nutrient use efficiency. Many long-term field trials have proven how K application can also boost NUE of P and other nutrients like S as reported by Perelman et al. (2021). Their studies had also shown that K can lessen negative effects of excess N applied to crop, thereby enhancing yields and health of crops ultimately the NUE of N.

4. CONCLUSION

Rapeseed-mustard variety PM-28 with combined application of N:P:K (19:19:19) @ 2% twice at 30 DAS and 45 DAS+$ZnSO_4$ @ 0.05% at 40 DAS+Boron (20%) @ 0.1% at 50 DAS performed best for obtaining higher seed yield, oil yield, protein yield, nutrient uptake and use efficiency over other varieties and enhancing productivity

crop quality of *utera* rapeseed mustard in rice fallows of lower Indo-Gangetic plains.

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