https://doi.org/10.17576/serangga-2024-2903-04

FOLIAR APPLICATION OF COMMERCIALLY AVAILABLE MICRO AND MACRONUTRIENTS FOR THE MANAGEMENT OF FLOWER THRIPS AND POD BORERS OF MUNG BEAN

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Received: 31 October 2023; Acceptance: 13 May 2024

ABSTRACT

The production of mung bean is facing a serious threat from insect pests, notably the flower thrips (*Megalurothrips distalis*) and pod borers (*Maruca vitrata, Helicoverpa armigera, Spodoptera litura, Eucrysops* sp.). In response, growers often resort to chemical pesticides, despite their adverse environmental and health impacts. However, an alternative approach involves substituting chemical pesticides with foliar applications of micro and macronutrients, proven effective in controlling insect pests in various crops. This study investigated the efficacy of such nutrients against flower thrips and pod borer infestations in mung bean. Conducted over two consecutive years (2020 and 2021) at the Pulses Research Centre, Bangladesh Agricultural Research Institute (BARI), Ishurdi, Pabna, and Regional Agricultural Research Station, BARI, Rahmatpur, Barishal, Bangladesh, the research reveals those foliar nutrient applications notably reduced flower thrips infestation in 2020, albeit to a lesser extent in 2021. The most substantial reduction in flower infestation occurred in plots treated with Thiovit (80% Sulphur) and Nutra-phos (24% Phosphorus+20% Calcium+6% Sulphur+12% Zinc) at the range of 13.5-24.5 and 13.5-18.6%. Nutrient applications also significantly decreased pod borer infestation, with the greatest reduction (36.0-40.0%) observed in plots sprayed with Muriate of Potash (60% Potassium) in both years, followed by Nutra-phos, Thiovit and McChili+Solubor (Zn:10%+B:20%). Although yield increased non-significantly compared to the control in both years and locations, the highest yield was observed in Nutra-phos sprayed plots (1112.0-1865.0 kg/ha), followed by Thiovit. However, the greatest benefit was derived from Thiovit, followed by Nutra-phos and McChili+Solubor treated plots. In conclusion, Thiovit, Nutra-phos or McChili+Solubor are recommended for foliar application in mung bean cultivation to effectively control flower thrips and pod borer infestations, offering both efficacy and cost-efficiency as alternatives to chemical pesticides.

Keywords: Eco-friendly, mung bean, thrips, infestation, nutrient

ABSTRAK

Pengeluaran Kacang Hijau menghadapi ancaman serius dari serangga perosak, terutamanya thrips bunga (*Megalurothrips distalis*) dan pengorek buah (*Maruca vitrata, Helicoverpa armigera, Spodoptera litura, Eucrysops* sp.). Sebagai tindakannya petani sering menggunakan racun perosak kimia, walaupun memberikan kesan buruk terhadap alam sekitar dan kesihatan. Walau bagaimanapun, pendekatan alternatif yang melibatkan penggantian racun perosak kimia dengan aplikasi mikro dan makronutrien terbukti berkesan dalam mengawal serangga perosak ke atas pelbagai tanaman. Kajian ini bertujuan mengenalpasti keberkesanan nutrien terhadap thrip bunga dan serangan pengorek buah ke atas Kacang Hijau. Kajian selama dua tahun berturut-turut (2020 dan 2021) di Pusat Penyelidikan Pulses, Institut Penyelidikan Pertanian Bangladesh (BARI), Ishurdi, Pabna dan Stesyen Penyelidikan Pertanian Serantau, BARI, Rahmatpur, Barishal, Bangladesh, mendedahkan bahawa aplikasi nutrien daun mengurangkan serangan thrip bunga pada tahun 2020 dan pada tahap yang lebih rendah pada tahun 2021. Terutamanya, pengurangan paling ketara dalam serangan bunga berlaku dalam plot yang dirawat dengan Thiovit (80% Sulphur) dan Nutra-phos (24% Fosforus+20% Kalsium+6% Sulfur+12% Zink) pada julat 13.5-24.5 dan 13.5-18.6%. Aplikasi nutrien juga telah mengurangkan serangan pengorek buah ketara, dengan pengurangan terbesar (36.0-40.0%) diperhatikan dalam plot yang disembur dengan Muriate of Potash (60% Kalium) pada kedua-dua tahun, diikuti oleh Nutra-phos, Thiovit dan McChili+Solubor (Zn: 10%+B:20%). Walaupun hasil meningkat secara tidak ketara berbanding kawalan pada kedua-dua tahun dan lokasi, hasil tertinggi diperhatikan dalam plot semburan Nutra-phos (1112.0-1865.0 kg/ha), diikuti oleh Thiovit. Walau bagaimanapun, hasil terbesar diperoleh daripada Thiovit, diikuti oleh plot dirawat Nutra-phos dan McChili+Solubor. Kesimpulannya, Thiovit, Nutra-phos atau McChili+Solubor disyorkan dalam penggunaan penanaman Kacang Hijau untuk mengawal thrip bunga dan serangan pengorek buah dengan berkesan, serta menawarkan kedua-dua keberkesanan dan kecekapan kos sebagai alternatif kepada racun perosak kimia.

Kata Kunci: Mesra Alam, Kacang Hijau, thrips, serangan, nutrien

INTRODUCTION

Mung bean (*Vigna radiata*) is a significant pulse crop of several Asian countries including Bangladesh. It has a broad global distribution, especially in tropical and subtropical regions, with South and Southeast Asia serving as the primary cultivation zones (Chadha 2010). Mung bean seeds are rich in minerals and protein, while immature grains, consumed as vegetables, offer plant protein, fiber, antioxidants, and phytonutrients with health benefits (Dahiya et al. 2013). Bangladeshi farmers are increasingly interested in cultivating mung beans during late winter in the southern regions and in the summer season in the northwestern and southwestern regions of the country. However, mung bean production is severely impacted by various insect pests, both in the field and in storage, leading to substantial yield losses (Paramita et al. 2022; Rahman et al. 2000).

Among the insect pests, flower thrips (*Megalurothrips distalis*) and pod borers (*Maruca virtata*, *Helicoverpa armigrea, Spodoptera litura, Eucrysops* sp.) are significant contributors to the challenges in mung bean production. Thrips primarily damage the tender buds and flowers of mung bean (Lal 1985), leading to significant flower shedding and yield loss. Pod borers, on the other hand, damage leaves, flower buds and feed on the developing seeds inside the pods. This pest can cause up to 14.3% pod damage and grain loss of 136 kg/ha. Unfortunately, farmers often do not take action to control these insect pests due to the low-profit margin associated with mung bean cultivation. However, with the recent increase in mung bean prices and growing awareness, farmers are now demanding pest control measures. Currently, the only method available for controlling these pests is the use of broad-spectrum insecticides. However, insecticides are expensive, and many poor farmers in Bangladesh cannot afford to use them. Furthermore, the use of insecticides is not environmentally friendly, as these chemicals disrupt the natural balance of the agro-ecosystem, contribute to insecticide resistance, and increase female fertility and mortality of biological control agents.

Overuse of insecticides has also led to an increase in the frequency of resistant individuals to the main insecticide ingredients, resulting in higher production costs and reduced efficiency in system management and environmental susceptibility. Therefore, there is a pressing need to develop eco-friendly alternative methods for managing these pests. Agronomic practices such as the foliar application of micro and macronutrients have proven to be highly effective in managing insect pests in various countries worldwide (Bala et al. 2018). The excessive use of nitrogenous fertilizers generally leads to an increase in pest incidence, whereas the application of phosphate and potassium fertilizers has been found to reduce the occurrence of certain pests (Reddy et al. 2017). The impact of micronutrients on crop growth and subsequent infestation by sucking pests, such as thrips, leafhoppers, whiteflies, and borers, was found to be significant. In plots where micronutrients were sprayed, the infestation of these pests was relatively lower compared to the control group in okra (Ali et al. 2012). This empirical practice not only helps in keeping mung bean flower thrips and pod borers at economically manageable levels but also proves to be environmentally safe and beneficial for the nutritional status of the plants. Therefore, the aim of this study is to evaluate the influence of the application of micro and macronutrients on flower thrips and pod borers in mung bean, to achieve higher yields.

MATERIALS AND METHODS

Study Location

The research was conducted at the Pulses Research Centre, Bangladesh Agricultural Research Institute (BARI) in Ishurdi, Pabna, Bangladesh (coordinates: 89°06'57.10" E, 24°12'93.30" N), and the Regional Agricultural Research Station, BARI in Rahmatpur, Barishal, Bangladesh (coordinates: 90°17'29.9.84" E, 22°78'81.20" N), throughout two consecutive seasons in 2020 and 2021.

Targeted Micro and Macronutrients

The micro and macronutrients used in this investigation were procured from a locally accessible commercial market, as specified below (Table 1).

Table 1. List of micro and macronutrients used for the management of flower thrips and pod borer complex infesting mung bean

Micro and macronutrients	Trade name	Manufacturer
Zinc+Boron+Manganese	Microvit 80 WP	Global Agrochemicals Limited, Dhaka
Sulphur (80%)	Thiovit 80 WG	Syngenta Bangladesh Lid., Dhanmondi, Dhaka-1205, Bangladesh.
Phosphorous(24%)+Calccium (20%)+Sulphur(6%)+Zinc(12%)	Nutra-phos-24	Yara UK Ltd. United Kingdom.
Zinc (10%)	McChili	JASS AGRO LTD., Dhaka, Bangladesh

Boron (20%)	Solubor	Auto Crop Care, Dhaka, Bangladesh.
Potashium (60%)	Muriate of Potash	Canpotex Limited, Saskatoon, Canada.

The experiment comprised treatments representing the application of micro and macronutrients at various growth stages of mung bean. These treatments were designated as follows:

T_1 = Microvit 80 WP (Zn, B & Mn) at 1 g/L
T_2 = Thiovit 80 WG (S 80%) at 2 g/L
T_3 = Nutra-phos 24 (P_2O_5 24%, Ca 20%, S 6%, & Zn 12%) at 3 g/L
T_4 = McChili (Zn 10%) at 0.35 g/L + Solubor (B 20%) at 1 g/L
T_5 = Muriate of Potash at 10 g/L
T_6 = Untreated control.

Experimental Design
The experiment followed a randomized complete block design with three replications, and treatments were randomly assigned within each block. In Barishal, BARI Mung-6 seeds were sown on February 10 and 01 in 2020 and 2021, respectively, with a row spacing of 30 cm. In Ishurdi, the seeds were sown on March 24 and 25, 2020 and 2021, respectively, also with a row spacing of 30 cm. Each plot measured 4m x 3m.

Before sowing, urea, triple super phosphate, Muriate of Potash, and boric acid were applied at rates of 40.0, 90.0, 40.0, and 7.5 kg per hectare, respectively, as basal doses during final land preparation. Flood irrigation followed sowing to ensure adequate soil moisture for germination and optimal plant establishment. Plant density was maintained by spacing plants 7 cm apart. Foliar application of micro and macronutrients was conducted four times: first at the onset of vegetative growth (3 trifoliate leaf stage), second at full vegetative growth (5 trifoliate leaf stage), third at 100% flowering stage, and fourth at 100% podding stage. Data on flower infestation and thrips population were collected at 100% flowering and podding stages by examining 20 opened flowers from two rows on each side of the plot. Adult and immature thrips were counted on a white paper board. The central four rows were not disturbed in order to record yield data. At maturity, pods from 10 randomly selected plants from the central four rows of each plot were collected and assessed for infestation.

Percentage of Infestation and Data Analysis
The number of infested and total pods were recorded to determine percent pod infestation using the appropriate formula (Hossain et al. 2020).

$$\%\ \text{Pod infestation} = \frac{\text{Number of infested pods}}{\text{Total number of pods}} \times 100$$

The pods harvested from the central four rows of each plot were threshed and then the grains were cleaned and dried in bright sunshine. The grain yield from the central four rows of each plot was converted into yield per hectare. Statistical analysis of the experimental data was performed using Statistix 10 software. The percentage of pod infestation data was square root-transformed for statistical analysis. Mean comparisons for treatment parameters were conducted using the LSD All-Pairwise Comparisons Test at a significance level of 5%. The marginal benefit cost ratio (MBCR) was calculated based on the prevailing market prices of mung bean and the cost of micro and macronutrients, as well as their spraying. The calculation of the marginal benefit cost ratio is as follows (Hossain et al. 2020):

$$\text{Marginal BCR (over control)} = \frac{\text{Marginal benefit over control}}{\text{Marginal cost over control}}$$

RESULTS AND DISCUSSION

Effect of Foliar Application of Micro and Macronutrients on Flower Infestation and Thrips Population in Mung Bean

The efficacy of foliar application of micro and macronutrients in mitigating flower infestation and thrips population in mung bean cultivation are shown in Table 2. In Ishurdi during 2020, Thiovit-treated plots demonstrated the lowest flower infestation percentage at (78.3%), statistically similar to Nutra-phos and other nutrient treatments, markedly contrasting with the untreated control's 91.7%. The reduction in flower infestation, ranging from 5.5% to 14.6%. underscores significant efficacy, with Thiovit achieving the highest reduction at 14.6%, statistically similar to Nutra-phos. The thrips population in the infested flowers did not significantly differ among the treatments, ranging from 2.20 to 2.78 per infested flower. In the subsequent year (2021), Nutra-phos-treated plots showed the lowest flower infestation rate at (60.6%), statistically akin to Thiovit and other nutrient treatments, contrasting with the untreated control at 70.0%. Thrips populations again showed no significant variation among treatments, , yet nutrient-treated plots maintained lower counts.

In Barishal during 2020, nutrient application yielded a significant reduction in flower infestation, with Thiovit-treated plots showcasing the lowest flower infestation at 67.5%, statistically similar to Nutra-phos and other nutrient treatments, juxtaposed with the untreated control at 89.4%. Nutra-phosThrips population per flower did not significantly vary among treatments and ranged from 2.2 to 2.3 per infested flower. In the 2021, Nutra-phos-treated plots displayed the lowest flower infestation at 63.1%, statistically similar to other nutrient treatments, while the untreated control reached 77.5%. Thrips population per flower remained consistent among treatments and ranged from 1.5 to 1.8 per infested flower (Table 2).

Table 2. Results of foliar application of micro and macronutrients on flower infestation and thrips population in mung bean during 2020 and 2021 at Ishurdi and Barishal

Year	Treatments	Flower Infestation By Thrips (%)		Infestation Reduction Over Control (%)		Mean Number Of Thrips/Infested Flower		Reduction Of Thrips Over Control (%)	
		Isd.	Bar.	Isd.	Bar.	Isd.	Bar.	Isd.	Bar.
2020	Microvit 80 WP	85.00 ab	79.38 a	7.28	11.19	2.51 a	2.24 a	9.71	8.57
	Thiovit 80 WG	78.33 b	67.50 b	14.55	24.48	2.35 a	2.29 a	15.47	6.53
	Nutra-phos-24	78.33 b	73.13 ab	14.55	18.18	2.25 a	2.31 a	19.06	5.71
	McChili + Solubor	83.33 ab	80.63 a	9.10	9.79	2.20 a	2.24 a	20.86	8.57
	Muriate of Potash	86.67 ab	81.88 a	5.45	8.39	2.39 a	2.41 a	14.03	1.63
	Untreated control	91.67 a	89.38 a	-	-	2.78 a	2.45 a	-	-
2021	Microvit 80 WP	62.78 A	66.88 A	10.31	13.71	1.73 A	1.61 A	7.49	11.03
	Thiovit 80 WG	60.56 A	66.25 A	13.49	14.52	1.73 A	1.63 A	7.49	10.34
	Nutra-phos-24	60.56 A	63.13 A	13.49	18.55	1.70 A	1.53 A	9.09	15.86
	McChili + Solubor	63.00 A	68.13 A	10.00	12.10	1.73 A	1.59 A	7.49	12.41
	Muriate of Potash	61.67 A	67.50 A	11.90	12.90	1.75 A	1.66 A	6.42	8.28
	Untreated control	70.00 A	77.50 A	-	-	1.87 A	1.81 A	-	-

Isd. = Ishurdi, Bar. = Barishal
Note: All means marked with the same letters within each column in a given year were not significantly different, as determined by the LSD All-Pairwise Comparisons Test at a 5% level of significance.

Foliar Application of Micro and Macronutrients on The Incidence of Pod Borer in Mung Bean

The application of micro and macronutrients in mung bean cultivation yielded a significant reduction in pod borer infestation levels, as shown in Table 2. In Ishurdi, throughout the year 2020, the prevalence of infestation fluctuated within the range of 7.0% to 11.7%, contingent upon the efficacy of the applied micro and macronutrients in combating the borer species. Notably, the lowest infestation rate of 7.0% was documented in plots subjected to Muriate of Potash application, exhibiting comparability with the outcomes obtained from Thiovit and Nutra-phos treatments, as well as McChili+Solubor and Microvit applications. Conversely, the highest infestation rate of 11.7% was observed in the untreated control plots. The relative reduction in pod borer infestation, in comparison to the control, spanned from 12.9% to 40.0%. Remarkably, the most pronounced reduction percentage of 40.0% was recorded in plots treated with Muriate of Potash followed by Thiovit (34.3%) Nutra-phos (34.3%), McChili+Solubor (22.9%)-treated plots. Transitioning to the year 2021, the pod borer infestation levels ranged between 7.9% and 12.8%. While the lowest infestation rate of 7.9% persisted in plots treated with Muriate of Potash, statistical insignificance among treatments was noted. Conversely, the untreated control plots exhibited the highest infestation rate of 12.8%. Reductions in pod borer infestation, relative to the control, ranged from 15.7% to 37.9%. Once more, the most notable reduction of 37.9% was observed in plots treated with Muriate of Potash followed by Nutra-phos, Nutra-phos, Thiovit, Microvit and McChili+Solubor-treated plots.

In Barishal, during the year 2020, the infestation of pod borers ranged from 27.1% to 42.9%. It is noteworthy that the lowest infestation of pod borers (27.1%) was observed in plots treated with Muriate of Potash, followed by plots treated with McChili+Solubor, Nutra-phos, Thiovit, and Microvit. However, there was no statistically significant difference among the treatments except for the control group. In the subsequent year, 2021, pod borer infestation levels fluctuated between 45.1% and 72.9% . Once more, the lowest infestation rate of 45.1% was observed in plots treated with Muriate of Potash, followed by those treated with Nutra-phos, McChili+Solubor, Microvit, and Thiovit. Statistical insignificance among treatments was again noted, except when compared to the untreated control group.

The findings of this study underscore the efficacy of foliar application of micro and macronutrients in managing flower thrips and pod borer infestations in mung bean cultivation. Notably, significant reductions in flower thrips infestation were observed in plots treated with Nutra-phos and Thiovit, while the highest reduction in pod damage caused by pod borers occurred in plots subjected to Muriate of Potash application, closely followed by Thiovit and Nutra-phos treatments. Several factors may account for the observed superior performance of foliar-applied micro and macronutrients. Firstly, mung bean exhibits a relatively short growth duration compared to many other pulses, particularly during the summer and winter seasons. However, its growth period is notably protracted, spanning 55 to 70 days in the northern and southern regions of Bangladesh. This extended growth window potentially facilitates more thorough assimilation and utilization of nutrients supplied through foliar application. In contrast to conventional soil applications of recommended fertilizer doses (RDF), which undergo complex chemical transformations in the soil before plant uptake (Dass et al. 2022; Kavita et al. 2017), foliar applications at critical growth stages such as vegetative growth (3 trifoliate leaved stage and 5 trifoliate leaved stage), flowering stage, and podding stage allow direct nutrient absorption by plant leaves. This direct assimilation enables enhanced photosynthesis and regulation of metabolic processes within the plant, thereby enhancing overall plant health and resilience against pest attacks (Dass et al. 2022;

Kavita et al. 2017). The notable success observed with foliar applications of Nutra-phos, Thiovit, and Muriate of Potash, which contain a blend of phosphorus, calcium, sulfur, zinc, and potassium during these crucial growth stages, facilitates the synthesis of essential compounds such as amino acids, sugars, enzymes, phenols, and alkaloids (Palaniapan & Annadurai 1999). These compounds play pivotal roles in fortifying plant resistance and tolerance to insect pests, as documented in previous research (Asiwe 2009; Khan et al. 2015; Pandey 2010). Indeed, these findings are consistent with previous studies demonstrating the effectiveness of micro and macronutrient applications in mitigating insect pest infestations in various field crops. For instance, prior research has identified a negative correlation between potassium content in rice plants and the presence of brown plant hoppers, underscoring the importance of adequate potassium availability in fortifying plant structures against insect feeding (Dash et al. 2007). Rashid et al. (2013) noted that increased potassium application led to a decrease in the population build-up of the rice brown plant hopper. Elevated potassium levels can boost secondary compound metabolism, diminish carbohydrate accumulation, eliminate specific amino acids, and augment the silica content of leaves and plants, consequently mitigating damage from insect pests (Facknath & Lalljee 2005; Krauss 2001). Adequate potassium availability has been found to enhance the fortification of plant structures, including the reinforcement of the cuticle, the outer wall of the epidermis, cell walls, and the development of sclerenchymatous tissues. This process also stimulates lignification and silicification, resulting in thicker and sturdier stems. The strengthening of plant structures is widely recognized as a means to enhance resistance against insect feeding (Howe & Jander 2008). Similarly, studies have shown a negative correlation between the sulphur and zinc content in rice foliage and the presence of brown plant hoppers (Dash et al. 2007), highlighting the significance of foliar fertilization in enhancing plant mineral status and resilience against stressors such as insect pests, ultimately contributing to increased crop yield potential (Khan et al. 2015; Kolota & Osinska 2006).

Foliar Application of Micro and Macronutrients on The Yield of Mung Bean

The yield performance of mung bean crops was subject to fluctuations based on the levels of thrips and pod borer infestations, which were intricately influenced by the application of micro and macronutrients. Despite these variances, discernible differences in yield among the treatments were not statistically significant. In Ishurdi during 2020, the highest recorded yield stood at 1112.0 kg/ha, emanating from plots treated with Nutra-phos closely followed by those subjected to McChil+Solubor, Thiovit, Microvit, and Muriate of Potash applications. Conversely, untreated control plots yielded the least, at 968.0 kg/ha. Yield increments over untreated controls ranged from 2.6% to 14.9%, with Nutra-phos treated plots exhibiting the most substantial increase at 14.9%, followed by McChili+Solubor, Thiovit, Microvit, and Muriate of Potash treatments (Table 3). In the subsequent year, 2021, significant yield variations among treatments were observed. Once again, Nutra-phos treatments yielded the highest at 1865.0 kg/ha, statistically similar to yields from McChil+Solubor, Thiovit, and Microvit treatments, followed by Muriate of Potash. The untreated control plots yielded the least at 1480.0 kg/ha. The yield increments over untreated controls ranged from 7.5% to 26.0%, with Nutra-phos treatments displaying the highest increase.

In Barishal during 2020, no statistically significant differences were noted in mung bean yields among treatments. The highest yield, recorded at 1169.0 kg/ha, was achieved from Nutra-phos treated plots, followed by Thiovit, McChil+Solubor, Microvit, and Muriate of Potash treatments. Conversely, untreated control plots yielded the least at 1043.0 kg/ha. Yield increments over untreated controls ranged from 3.6% to 12.1%, with Nutra-phos treatments exhibiting the highest increase at 13.2%, followed by Thiovit, McChili+Solubor, Microvit, and Muriate of Potash treatments. In the subsequent year 2021, significant variations in yield among treatments persisted. Nutra-phos treatments again yielded the highest at 1106.0 kg/ha, statistically at par with Thiovit and McChil+Solubor treatments, followed by Microvit and Muriate of Potash. The untreated control plots yielded the least at 980.0 kg/ha. Yield increments over untreated controls ranged from 7.7% to 12.9%, with Nutra-phos treatments displaying the highest increase at 12.9%, followed by Thiovit, McChili+Solubor, Microvit, and Muriate of Potash treatments (Table 3).

Application of micro and macronutrients via foliar spraying resulted in a reduction in flower thrips and pod borer infestation, consequently increasing grain yield. This could be attributed to enhanced plant resistance due to nutrient application, leading to increased flowering and podding, ultimately boosting yields. It's worth noting that across both locations and years, combinations of micro and macro nutrients sprayed plots showed higher reductions in flower and pod borer infestations, consequently influencing pod setting and minimizing pod damage in mung beans. Particularly noteworthy was the superiority of Nutra-phos treatments, containing a mixture of phosphorous, calcium, sulfur, and zinc, in terms of yield compared to Thiovit and McChili+Solubor treatments. Previous studies have demonstrated the positive effects of supplementary foliar fertilization on plant mineral status and crop yield (Dass et al. 2022; Khan et al. 2015; Kolota & Osinska 2006). In this study, foliar nutrition treatments were administered during key growth stages, potentially enhancing nutrient absorption by the leaves and consequently reflecting more in the final yield of the crop. Additionally, the vigor induced by the foliar application of micro and macronutrients might have influenced increased flowering and pod setting, ultimately resulting in higher yields compared to untreated crops. The observed yield increases resulting from foliar applications of Nutra-phos during the pod formation stage were mainly attributed to rises in the number of pods per plant, seeds per pod, and seed indices. This highlights the significance of foliar application of phosphorus, calcium, sulphur, and zinc in addressing nutrient deficiencies, thereby resulting in enhanced seed yields. The potential yield of mung bean is influenced by filled seeds achievable through foliar fertilizer application, a factor typically not attained before foliar application. (Das et al. 2016). Micronutrients such as zinc and boron play pivotal roles in regulating plant growth, influencing shoot development, electron transport, photosynthetic enzyme activity, and biomass production (Ghasemian et al. 2010). Furthermore, they are essential for chlorophyll synthesis, pollen function, and fertilization, thereby contributing significantly to crop yield enhancement (Dass et al. 2022; Kulhare et al. 2014).

Table 3. Impact of foliar application of micro and macronutrients on pod borer incidence and mung bean yield in Ishurdi and Barishal, 2020-2021

Year	Treatments	Pod Infestation By Borer (%)		Pod Infestation Reduction Over Control (%)		Yield (Kg/Ha)		Yield Increase Over Control (%)	
		Isd.	Bar.	Isd.	Bar.	Isd.	Bar.	Isd.	Bar.
2020	Microvit 80 WP	10.17 ab	31.80 b	12.85	26.04	1071 a	1100 a	10.64	5.47
	Thiovit 80 WG	7.67 b	30.27 b	34.28	29.50	1081 a	1135 a	11.67	8.82
	Nutra-phos-24	7.67 b	28.50 b	34.28	33.58	1112 a	1169 a	14.88	12.08
	McChili + Solubor	9.00 ab	27.38 b	22.88	36.71	1096 a	1120 a	13.22	7.38
	Muriate of Potash	7.00 b	27.14 b	40.02	36.02	993 a	1080 a	2.58	3.55
	Untreated control	11.67 a	42.87 a	-	-	968 a	1043 a	-	
2021	Microvit 80 WP	10.17 A	52.92 B	20.23	26.92	1707 AB	1058 B	15.34	7.96
	Thiovit 80 WG	9.92 A	56.00 B	22.19	23.07	1710 AB	1091 A	15.54	11.33
	Nutra-phos-24	9.08 A	48.47 B	28.78	33.11	1865 A	1106 A	26.01	12.86
	McChili + Solubor	10.75 A	50.17 B	15.69	31.04	1712 AB	1075 AB	15.68	9.69
	Muriate of Potash	7.92 A	45.14 B	37.88	37.07	1591 BC	1055 B	7.50	7.65
	Untreated control	12.75 A	72.89 A	-	-	1480 C	980 C	-	-

Isd. = Ishurdi, Bar. = Barishal

Note: All means marked with the same letters within each column in a given year were not significantly different, as determined by the LSD All-Pairwise Comparisons Test at a 5% level of significance.

Return and Marginal Benefit Cost Ratio (MBCR)

The return and marginal benefit cost ratios (MBCR) are presented in Table 4. In the Ishurdi region during the 2020 cropping season, plots treated with McChili+Solubor exhibited the highest additional return of 8960.0 Tk/ha, trailed by Thiovit and Microvit. Notably, Thiovit-treated plots demonstrated the highest benefit with an MBCR of 2.0, followed by McChili+Solubor with 1.6 and Microvit with 1.4. In the subsequent year, 2021, plots treated with Nutra-phos displayed the highest additional return of 26950.0 Tk/ha, followed by McChili+Solubor and Thiovit. However, Thiovit-treated plots exhibited the highest benefit with an MBCR of 4.0, followed by Nutra-phos with 3.6 and Microvit with 3.1.

In Barishal during 2020, plots treated with Nutra-phos showcased the highest additional return of 8820.0 Tk/ha, followed by Thiovit with 6440.0 Tk/ha and McChili+Solubor. However, the plots sprayed with Thiovit showed the highest benefit with a MBCR of 1.6, followed by Nutra-phos with a MBCR of 1.2. Similarly, in 2021, Nutra-phos-treated plots displayed the highest additional return of 8820.0 Tk/ha, followed by Thiovit and McChili + Solubor. However, Thiovit-treated plots demonstrated the highest benefit with an MBCR of 1.9, followed by Muriate of Potash with 1.5, Nutra-phos with 1.2, and McChili+Solubor with 1.2.

Across both locations and in most cases, Nutra-phos treated plots yielded the highest additional return. However, Thiovit-treated plots consistently demonstrated the highest marginal benefit, followed by Nutra-phos and McChili+Solubor treated plots. It's pertinent to note that Nutra-phos comprising a mixture of phosphorous, calcium, sulfur, and zinc, incurs higher costs compared to Thiovit and McChili+Solubor treatments, elevating mung bean cultivation costs by 83.2% and 30.3%, respectively. Consequently, the marginal benefit-cost ratios (MBCR) were higher in these two treatments than in other foliar nutrition treatments. Nevertheless, the corresponding improvement in yield resulting from the application of Nutra-phos resulted in the highest additional return but slightly lower marginal benefit compared to Thiovit and McChili+Solubor treatments.

Table 4. Cost and return analysis of foliar application of micro and macronutrients for controlling flower thrips and pod borer in mung bean during 2020 and 2021 at Ishurdi and Barishal

Year	Treatments	Yield (kg/ha)		Additional Yield Over Control (kg/ha)		Additional Return Over Control (Tk./ha)		Cost of Nutrients Application (Tk./ha)		Marginal Benefit Cost Ratio (MBCR)	
		Isd.	**Bar.**	**Isd.**	**Bar.**	**Isd.**	**Bar.**	**Isd.**	**Bar.**	**Isd.**	**Bar.**
2020	Microvit 80 WP	1071	1100	103	57	7210	3990	5200	5200	1.38	0.77
	Thiovit 80 WG	1081	1135	113	92	7910	6440	4040	4040	1.96	1.59
	Nutra-phos-24	1112	1169	144	126	10080	8820	7400	7400	1.36	1.19
	McChili+Solubor	1096	1120	128	77	8960	5390	5680	5680	1.58	0.95
	Muriate of Potash	993	1080	25	37	1750	2590	3500	3500	0.50	0.74
	Untreated control	968	1043	-	-	-	-	-	-	-	-
2021	Microvit 80 WP	1707	1058	227	78	15890	5460	5200	5200	3.06	1.05
	Thiovit 80 WG	1710	1091	230	111	16100	7770	4040	4040	3.99	1.92
	Nutra-phos-24	1865	1106	385	126	26950	8820	7400	7400	3.64	1.19
	McChili+Solubor	1712	1075	232	95	16240	6650	5680	5680	2.86	1.17
	Muriate of Potash	1591	1055	111	75	7770	5250	3500	3500	2.22	1.50
	Untreated control	1480	980	-	-	-	-	-	-	-	-

Isd. = Ishurdi, Bar. = Barishal

For calculating income and benefit the following market prices were used: Mung bean = Tk. 70.0/kg, Microvit 80 WP = Tk 1000.0/kg, Thiovit 80 WG = Tk. 210.0/kg, Nutra-phos-24 = Tk. 700.0/kg, McChili = Tk. 2400.0/kg, Solubor = Tk. 400.0/kg, Muriate of Potash = Tk. 15.0/kg; Labour wage for applying nutrients = Tk 400.0/day/labourer (8 h day).

CONCLUSION

In conclusion, the study provides valuable insights into the efficacy of foliar application of micro and macronutrients in mitigating flower thrips and pod borer infestation in mung bean cultivation. These findings hold promise for the adoption of sustainable pest management practices and offer cost-effective alternatives to chemical pesticides. It is recommended that foliar applications of micro and macronutrients, such as Thiovit, Nutra-phos, or McChili+Solubor, be integrated into mung bean farming practices to mitigate flower thrips and pod borer infestations effectively. The observed benefits of micro and macronutrient applications in mung bean cultivation may be attributed to enhanced plant resistance, leading to increased flowering and pod setting, thereby yielding higher crop yields compared to untreated plants. Future research endeavors could delve into optimizing nutrient formulations and application strategies to further enhance pest resistance and crop productivity in mung bean cultivation. Such efforts would not only contribute to the sustainability of agricultural practices but also bolster food security in the face of evolving pest pressures and environmental challenges.

ACKNOWLEDGEMENTS

The authors express their gratitude to the Australian Centre for International Agricultural Research (ACIAR) project "Incorporating Salt Tolerant Wheat and Pulses into Smallholder Farming Systems in Southern Bangladesh" for providing essential resources for the development and execution of this program and study.

AUTHORS DECLARATION

Funding Statement

The financial support was granted by the Bangladesh Agricultural Research Institute, Bangladesh under the ACIAR project for which the authors are very grateful.

Conflict of Interest

The authors declare that they have no conflict of interest.

Ethics Declarations

Ethics declarations are not applicable for this research.

Data Availability Statement

This manuscript has no accessible data.

Authors' Contributions

Md. Altaf Hossain (MAH) conceptualized, designed, conducted a part (Ishurdi) of the experiments, and wrote the original manuscript. M. Mahbubur Rahman (MMR) conducted another part (Barishal) of the research and wrote the manuscript. MMR, MAH, and Md. Ahsanul Haque (MAH) analyzed and interpreted the data, reviewed and edited the manuscript. All authors read and approved the manuscript.

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