FIELD PERFORMANCE OF DIFFERENT MANAGEMENT APPROACHES AGAINST THRIPS (*Scirtothrips dorsalis* Hood.) FOR IMPROVED GROWTH AND YIELD OF CAPSICUM (*Capsicum annuum* L.)

A THESIS

BY

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A Thesis (Course No. HRT-6104) Submitted to the Agrotechnology Discipline in Partial Fulfillment of the Requirements for the Degree of Master of Science

AGROTECHNOLOGY DISCIPLINE
LIFE SCIENCE SCHOOL
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Dedicated

To

My Beloved Parents

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ABSTRACT

Thrips infestations is the main impediment for capsicum production in open field condition. Thrips is considered as one of the major harmful and production threatening pests in capsicum throughout the cultivation period. Keep in mind public concern about over pesticides use to control pests in vegetables, the present management approaches were undertaken to minimize thrips infestation in capsicum production. A field experiment was carried out at Professor Dr. Purnendu Gain field laboratory, Khulna University to assess the efficacy of different management methods on different colors producing capsicum plants to reduce thrips infestation during cultivation and to analyze the profitability under field condition. The factorial experiment consisted of twelve treatments [Factor A (3): capsicum colors (green, yellow, purple), Factor B (4): applications [kaolin, neem oil, chemical (Bildor), control] using Randomized Complete Block Design with three replications. It was found that growth, yield components, yield of capsicum and profitability were significantly influenced by different capsicum colors and treatments. Overall, the purple color and kaolin treated plants resulted in better vigor, plant height, leaf number and chlorophyll content than control plants. The results revealed that the highest fruit yield (44.86 t ha^{-1}) was recorded in purple color with kaolin application combination in compared to green color plus untreated plants (control) (16.12 t ha^{-1}). Moreover, flowering occurred earlier by more than 4 days in plants that treated with kaolin compared to the untreated plants (control). In addition, kaolin application was lowered thrips infestation by 73.76 % than control plants. The cost-saving plus higher yields contributed to net profitability of Tk. 27,07,828 ha^{-1}. Therefore, if the farmers want to boost up the current capsicum production following ecofriendly management approaches in Bangladesh as well as to support the country's demand, the purple color with kaolin application system may be one of the best possible options.

Keywords: purple capsicum, thrips, ecofriendly, kaolin, profitability.

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CHAPTER I

INTRODUCTION

Capsicum (*Capsicum annuum* L.) is one of the most important high-value horticultural crops grown extensively throughout the world, especially for its' taste and nutritional enrichment. The vegetable is also famous for its attractive colors especially purple, yellow and red. It is nutritionally rich fruits especially Vitamin A and C (Kaur and Singh, 2013). Reports suggested that the crop shows tremendous growth performance in the temperate climate even though efforts are on the motion for growing sweet pepper in tropical and subtropical countries since last few decades (Bhatt et al., 1999). In Bangladesh, some adventurous or amateurish farmers sporadically cultivate this crop on small scale to fulfill the local demand of urban areas (Saha and Salam, 2004). Predicting an ample scope of capsicum as vegetable BARI developed two cultivars of it through several years research, which is now commercially cultivated in northern parts of Bangladesh along with BARI ambient regions. While the southwestern region of Bangladesh (SWRB) which is little to moderate saline is entirely devoid of the adaptability check for the cultivation of capsicum. Several global research findings denote that capsicum has the potential to tolerate salinity to low extent with maintaining a standard economic yield (Morales-Garcia et al., 2011). Consequently, a new avenue has been opened for the cultivation of capsicum in SWRB ensuring higher crop intensity and diversity.

One of the major problems of capsicum cultivation is thrips (*Scirtothrips dorsalis* Hood.) infestation throughout the cultivation period. It has been reported that over thirty-five (35) species of insects and pests are devastating for pepper (Sorensen, 2005). Previous research indicated that thrips is one of the harmful and production threatening insects in sweet pepper cultivation in India (Vasicek et al., 2001; Reddy and Kumar, 2006). Reddy (2005) stated that sweet pepper was mostly infected by thrips which is considered as one of the major pests of pepper both under protected and field conditions. The incidence of aphids, thrips and mites was so acute in capsicum and the severe infestation could incur 100% crop loss. The typical symptoms of thrips infestation consist of upward rolling of leaf, squeeze of leaf size, distorted and twisted leaves, discoloration and scarring of developing fruits due to sucking of cell sap from leaves and emerging flowers by adults and nymphs (Sanap and Nawale, 1987). Indirectly thrips can damage pepper plants by transmitting tomato spotted wilt virus (TSWV) which is one of the major viral diseases of pepper (German et al., 1992). It is always problematic to control thrips due to their high multiplication rate, cryptic behavior, and short life cycle (Cloyd, 2009). It is so important to monitor thrips population and restraining its growth to prevent the epidemic. The control measures can be accomplished by several approaches viz. cultural, mechanical, physical, and biological (Mouden et al., 2017).

Crops raised under protected structures are always safer in comparison to open fields. Crops grown under protected structures are so common in developed countries to control unfavorable environments and exclude arthropod insects and pests (Berlinger et al., 1999). However, previous research revealed that crops grown under photo-selective shading nets result in higher physiological response with less risk of pests (Rajapakse and Shahak, 2007). However, kaolin, an organic mineral compound rich in kaolinite, has widespread use in mitigating heat, drought stress, and reduce insect infestation in various crops. The white kaolin (Surround® WP) forms a particle film on the leaf surface, which increases the reflection of incoming solar radiation, changing the radiation and heat balance and reducing the risk of heat stress from high temperatures and solar injury. Also, the white layers adhering to the leaf surface causing irritation for insects and helps to eliminate their scavenging activity on the leaves and fruits of crops. This clay suspension helps to repel different type of insects like thrips. Mites, beetles, leaf roller etc. (Glenn, 2012).

Chemical methods are always dominated over botanicals to control any insects and pests of crops. Patel and Kumar (2017) reported that among three botanicals neem oil sprayed at 2.5 mlL^{-1} showed better performance and control 53.22% thrips population on chili cultivation in Allahabad (U.P.), India. Although the chemicals Spinosad at 0.2 mlL^{-1} was recorded highest control of thrips (79.79%). Similarly, neem soap at 1% showed better results over other botanicals to control thrips on capsicum under net house reported by Kaur and Sing (2013). Mandi and Senapati (2009) stated that ultineem at 1% showed better performance and control 54.2% thrips population. But chemicals dominated over botanicals and acetamiprid at 0.004% reduced 93.3% thrips population on chili. One of the common methods to control thrips is chemical method. But the control of insects and pests by using chemicals is not desired approach as it can ruin beneficial insects too and consequently insects become resistant against insecticides.

Partial budgeting is an effective tool used to evaluate the costs and benefits related to a precise change in a farm. This tool, explicitly focuses on the consequences of the projected change in a farming system. This budgeting style is named partial because it does not comprise all costs, but only those which are altered from the farmer's present production practices to the projected one(s) (Cornelisse, 2017; Roy, 2018).

Keep in mind public concern about pesticides used in vegetables, the present eco-friendly approaches would be the potential to minimize thrips infestation in capsicum production. Now-a-days the whole universe is looking for integrated pest management (IPM) approach and trying to minimize the use of chemicals and produce safe foods for people. The work on an eco-friendly management approach to control the thrips population on capsicum production in Bangladesh is meager. Also, as a comparatively new high-value crop in the southwestern region of Bangladesh, capsicum has no recommended eco-friendly management approaches to minimize the thrips population on capsicum. So, it is hypothesized that capsicum could be cultivated in the Southwestern region with fewer thrips infestation ensuring higher yield and economic return than the traditional capsicum production system. The present study was undertaken with the following objectives:

1. To assess the efficacy of different management methods to reduce thrips infestation in capsicum production under field conditions in Southwestern Bangladesh.
2. To analyze the profitability of using different management approaches to minimize thrips infestation in capsicum by partial budgeting.

CHAPTER II

REVIEW OF LITERATURE

Capsicum is an attractive, tasty, luscious and nutritious fruit that belonging to the Solanaceae family. About 35 species of insect and mite pest were reported in capsicum (Kaur and Singh, 2013). Among them, thrips are considered the major insect in capsicum. To ensure the improved growth and yield of capsicum, proper management approaches are needed. The present study was undertaken to investigate the field performance of different management approaches against thrips for successful capsicum production. Available research findings at home and abroad related to the present study are reviewed here.

2.1 Effect of capsicum genotype against thrips

Capsicum is available in diverse colors, such as green, red, black, orange, purple, etc. (Kumar et al., 2015). s grown worldwide for cooked vegetables, salad pickles, and processing purposes. The reason behind its worldwide admiration is its delicate taste, pleasant, flavor, and varied colors with nutritious qualities. Its beautifully shaped form and vivid diverse color entitled it "The Christmas ornaments of the vegetable world" (Sharma et al., 2019). However, work on the evaluation of chilli genotypes against thrips, *S. dorsalis* has been reported by several workers (Kaur et al., 2010; Singh and Singh, 2009; Roopa, 2013).The variation in damage may be due to the differential load of the thrips population on different genotypes based on the morphological and biochemical variations in plants. The genotypes which are highly susceptible may be more preferred by the thrips due to thin leaf, low chlorophyll and phenol content might have favored more thrips population and thrips feeding damages the leaves, reducing the photosynthetic capacity, resulting in reduced fruit production (Shipp et al., 1998). Any leaf character that interferes with the thrips life cycle is a potential resistance factor which may contribute to the mechanism of defense against thrips and mites. It is known that both morphological and chemical characters of leaves can play a role in defense against insects (Rosenthal and Kotanen, 1994). Rameash et al. (2016) reported that chlorophyll and total phenol content showed negative significant association with thrips incidence in chilli. Phenols have long been reported to provide resistance in plants during host plant interactions by several workers like Mondal et al. (2013) and Subhash et al. (2013) as it increases the unpalatability of the food materials which may be the possible reason for receiving low incidence of thrips. Simultaneously, higher total chlorophyll content resulted in dark colour may not attract thrips (Shaw et al., 1991). There is no single factor that responsible in thrips population fluctuation, but all the factors work in compliment with each other for the development of resistance in plants against thrips reaction. So, these morphological and biochemical factors play a vital role in fluctuating the thrips population.

2.2 Effect of biological control against thrips

Hoffmann et al. (1996) reported that beneficial organisms like ground beetles, lady bird beetles, minute pirate bugs, big-eyed bugs, lacewings, hover flies, predatory mites and spiders are helpful to suppress thrips population. A tiny wasp (*Megaphragma mymaripenne*) killed almost 50% of the eggs of greenhouse thrips in Southern California (Broughton and De Lima, 2002). Bara and Laing (2020) reported that entomopathogenic fungi specially *Beauveria bassiana* has potential to control the thrips biologically on avocado in South Africa. They mentioned that entomopathogenic fungi may be a substitute to synthetic chemicals for thrips control in avocado. Bennison et al. (2002) stated that the predatory mites *Gaeolaelaps aculeifer* (Hypoaspis) and *Aculeifer stratiolaelaps* (Hypoaspis) miles potential for controlling ground welling thrips. Avoiding the use of persistent pesticides along with dust help to conserve the beneficial insects which are helpful to control the thrips. Some of them are minute pirate bugs, predatory thrips like six spotted thrips, black hunter thrips, banded wing thrips, parasitic wasps, green lacewings etc. (Braley, 2021).

Vanisree et al. (2013) reported that Spinosad was found most effective in reducing the population of *Scirtothrips dorsalis* as well as in increasing yield. Similar results were also reported by Seal et al. (2006) with spinosad and most effective in reducing the density of *Scirtothrips dorsalis* up to (0.015%). Kumar et al. (2016) reported that Spinosad was found most effective in reducing the population of *Scirtothrips dorsalis* up to 81.77%. Vanisree et al. (2013) reported that Spinosad was found most effective in reducing the population of *Scirtothrips dorsalis* as well as in increasing yield. This result supported by Patel et al., (2009). Recorded among the treatments Spinosad the highest yield of (8.9 t ha^{-1}) with an increase of 219.37% yield over the untreated check and was found significantly superior to all the other treatments. Kumar et al. (2016) reported that application of Spinosad 45 SC @ 0.01 percent recorded the highest yield (3.0 t ha^{-1}). Spinosad is generally more effective than other botanicals against thrips (Jones et al., 2005).

Glenn (2012) reported that the white kaolin (Surround® WP) forms a particle film on the leaf surface, and the white layers adhering to the leaf surface causing irritation for insects and helps to eliminate their scavenging activity on the leaves and fruits of crops. This clay suspension helps to repel different type of insects like thrips, mites, beetles, leaf roller etc. Particle film of kaolin dramatically reduced the oviposition of *T. tabaci*. (Larentzaki et al., 2008). Around 50% flower thrips *(Frankliniella* spp.) within the canopy of rabbiteye blueberry plants was reduced by the efficiency of kaolin (Spiers et al.,2004).Thrips showed a distinct avoidance of kaolin-treated leaf discs in onion within the first 60 min of plant contact informed by Abd El-Aziz (2013).Kaolin particle film has several modes of activity, acts as a physical barrier, prevents insects from reaching vulnerable plant tissue, and it acts as a repellent by creating an unsuitable surface for feeding or egg laying. The uniform white film may also disrupt the insect's host-finding capability by masking the color of the plant tissue. Furthermore, particles of kaolin act as an irritant to the insect. After landing on a treated surface, particles of kaolin break off and attach to the insect's body, triggering an excessive grooming response that distracts the pest. It has been shown to be effective against several orchard pests, including thrips, apple maggot, white apple leafhopper and pear psylla (Puterka et al., 2000; Larentzaki et al., 2008).Although kaolin-based products are reportedly efficient against thrips (Puterka et al., 2000); the mechanisms of their action have not been demonstrated. Onion thrips numbers were significantly reduced after kaolin applications. As such, it may prove to be an important component of an integrated pest management program against *T. tabaci* in onions, limiting insecticide applications and reducing the risk of insecticide resistance, and offering an alternative control method for organic or small-scale growers. Kaolin-based products have been approved for organic use in fruit and vegetables crops (OMRI, 2007). However, because of the importance of a continuous coverage of plant material with kaolin particle film, multiple applications and better coverage than we experienced in the field will be required to cover newly expanding foliage. Furthermore, its use may be limited in areas where the film may be washed off by frequent rainfall or overhead irrigation.

2.3 Effect of chemicals control against thrips

Seal et al. (2006) reported that imidacloprid most effective in reducing the density of *Scirtothrips dorsalis* up to (0.015%). Sathyan et al. (2017) revealed Dimethoate 30 EC @ 0.15% was the effective treatment in percentage reduction of in the result Dimethoate @0.03% was the effective treatment in percentage reduction of chilli thrips were (63.24%) reduction over control. Kumar et al. (2016) reported that Dimethoate was found effective in reducing the population of *Scirtothrips dorsalis* up to (75.32%). Kaurand Singh (2013) conducted an experiment in Punjab Agricultural University, Ludhiana on capsicum under net house conditions. They obtained highest yield (0.215-0.239) kg plant^{-1} in capsicum with the use of Asataf 75 SP (Acephate)@ 0.05%, Confidor 17.8 SL (imidacloprid)@ 0.025% followed by Neem Soap (*Azadirechtaindica*)@ 1.0% and other treatments. Kandasamy et al. (1990) found that monocrotophos at 0.08% was the most effective in capsicum to reduce *Scirtothrips dorsalis*. They also found that the greatest cost: benefit ratio was obtained with methyl-0-demeton [demeton-0-methyl] at 0.025%.

Patil et al. (2018) resulted that, the treatment of fipronil 0.005 per cent found significantly superior in controlling the chilli thrips with significantly higher fruit yield. Hosamani et al. (2015) the results revealed that the Imidacloprid 17.8% SL recorded highest per cent reduction of thrips over untreated control. Samota et al. (2017) on the basis of mean per cent reduction in thrips population in all the three sprays the treatment of acetamiprid was found to be the most effective. Sandeep et al. (2017) reported that among insecticides, imidacloprid 17.8 SL reduced maximum thrips population (82.46%) as well as in increasing yield. Mandi et al. (2009) reported that acetamipride was found most effective in reducing the population of

Scirtothrips dorsalis as well as in increasing yield. Maity et al. (2015) Fipronil proved most promising in keeping the thrips population much lower as compared to control and producing the highest yield. Tripti and Ashwani (2018) Fipronil 5SC (1.02) was the most effective treatment indicating recorded lowest population of thrips (*Scirtothrips dorsalis* Hood) and producing the highest yield.

Rakesh (2017) results revealed that among the different treatments Imidacloprid proved to be the effective treatments followed by Pongamia oil, Neem oil. Imidacloprid 0.005% was the most effective treatment in percentage reduction of chilli with 67.58 % reduction over control. Also reported by Patel et al. (2009) and Seal et al. (2006). Patel et al. (2009) reported that Imidacloprid (0.01%) was most effective as it reduced the maximum larval population at each observational interval during first and second spray with highest marketable yield (27.93 tha^{-1}). Samota et al. (2017) reported that Imidacloprid 17.8%SL maximum yield of chilli. Among all the treatments Imidacloprid @ 0.2ml/L proved to be the best treatment followed by Neem oil + imidacloprid @ 2.5ml/L+0.1ml/L, NSKE + imidacloprid @ 50 g/L+0.1ml/L, Karanj oil + imidacloprid @ 10ml/L+0.1ml/L, Pongamia oil + imidacloprid @ 3ml/L+0.1ml/L, Garlic sap extract + imidacloprid 10g/L + 0.1ml/L, Tobacco oil + imidacloprid @ 3ml/L+0.1ml/L also effective in managing (*Scirtothrips dorsalis* H.) reduction.

It is revealed from the above review of literature that the work on the effect of different management approaches to reduce thrips in capsicum is meager as reported by different authors. Therefore, the present study was undertaken.

CAHPTER III
MATERIALS AND METHODS

This chapter describes the materials and methods that were used in carrying out the field experiment. The details of the materials used, and methods adopted in this experiment are presented in this section.

3.1 Experimental site

The experiments were conducted at Professor Dr. Purnendu Gain field laboratory of Agrotechnology Discipline, Khulna University, Bangladesh (22°47' N; 89°34' E) during winter season of 2020-2021 (November-May).

3.2 Climatic and soil condition

The experimental area was under the sub–tropical climatic zone characterized by relatively scanty rainfall, high humidity, high temperature and long day period during the Kharif season (April to September) and scanty rainfall associated with moderate low temperature and short-day period during the Rabi season (October to March). The temperature in the experimental field ranged from 22 to 34 °C, while relative humidity ranged 70-86% throughout the growing period. The soil was collected from the research farm of Khulna University to analysis the soil properties that consisting of 16% sand, 36% silt, 51% clay and 2.4% organic matter. It was reported that soil is slightly acidic (pH of 6.2) with an inherent exchangeable P, K, Ca, and Mg content were 2.1 Cmol kg^{-1}, 0.5 Cmol kg^{-1}, 15.5 Cmol kg^{-1}, and 10.5 Cmol kg^{-1} soil, respectively (SRDI, 2009). Field capacity of the soil was calculated according to Datta et al. (2009) where 44.8% soil moisture content was determined at 100% field capacity also corresponded 0 kPa soil water potential.

3.5.10 Fruit number and yield

Data on fruit number and yield were recorded during each harvesting and total yield was calculated.

Partial budget analysis for eco-friendly management approaches to minimize thrips infestation in capsicum production

The cost of plastic mulch, kaolin, pesticides and intercultural operations (land preparation, weeding, harvesting) according to market price were included for partial budgeting. A partial budget analysis was conducted summarizing the changes in revenue and expenses using different management approaches to crop thrips with untreated control plants.

3.9.11 Statistical analysis

The field data were subjected to a two-way analysis of variance (ANOVA) and were analyzed using the analytical software SAS following the GLM procedure and means with significant treatments effects were identified by F test and separated by Tukey's HSD test at $p < 0.05$. The Pearson Correlation analyses were performed to judge the pattern and strength of the relationship between canopy temperature and thrips incidence at different WAT. The partial budget analysis was computed by Excel 2016.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Growth and development parameters

4.1.1 Plant survival and vigor

Capsicum plants (purple, yellow, green) survives properly in open filed condition. There were no significant effect of different capsicum colors and applications on plant survival observed (Table 4.1). In case of plant vigor, at early stage [2 week after transplanting (WAT)] a significant effect of capsicum colors on plant vigor was documented and purple and yellow color producing capsicum plants grown more vigorously than green color capsicum plant, but applications had no significant effect on plant vigor. However, gradually the effect of capsicum colors and applications were maximized and the similar tread of plant vigor in respect of capsicum color was noticed at 4 WAT, and also application had significant effect on plant vigor, generally all types of applications (Kaolin. Neem oil, Bildor) performed better in respect of plant vigor than untreated plants (control).

Table 4.1. Effect of capsicum colors and applications on plant survival and vigor.

Treatments	Plant survival (%)		Plant vigor	
	2 WAT	4 WAT	2 WAT	4 WAT
Capsicum colors (A)				
Green	100.0	100.0	6.67 b	7.50 b
Yellow	100.0	99.0	8.00 ab	8.33 ab
Purple	100.0	99.0	8.25 a	9.17 a
Applications (B)				
Control	100.0	98.6	6.67	6.79 b
Kaolin	100.0	100.0	8.33	8.55 a
Neem oil	100.0	98.6	7.89	8.10 a
Bildor	100.0	100.0	7.67	7.80 a
Significance level (p- value)				
A	0.21	0.61	0.04	0.04
B	0.31	0.58	0.15	0.03
A × B	0.83	0.36	0.43	0.44

Means of same letters within each column do not differ significantly and Tukey's HSD test at $p < 0.05$ for multiple comparison, p-value indicates level of significance, WAT-Week after transplanting, kaolin was applied at 56 kg ha^{-1} as foliar sprays, neem oil was applied at 2 ml L^{-1}, and chemical (Bildor) was applied 2.5 ml L^{-1}.

4.1.2 Plant height

Capsicum colors and applications had significant effect on plant height except 2, 10, 12 WAT, respectively where no significant effect was noticed (Table 4.2). At 4 WAT, the maximum plant height (22.57 cm) was recorded from purple color producing capsicum plants followed by green color capsicum (18.94 cm) while in least in yellow color making capsicum plants (16.69 cm). In case of applications, kaolin clay showed better results for plant height than either chemical or neem oil and untreated plants (control) at 4 WAT. All applications contributed better for increasing plant height than control plants at 6 WAT. In 8 WAT, kaolin clay and chemical applications exhibited better results for plant height than neem oil and control plants.

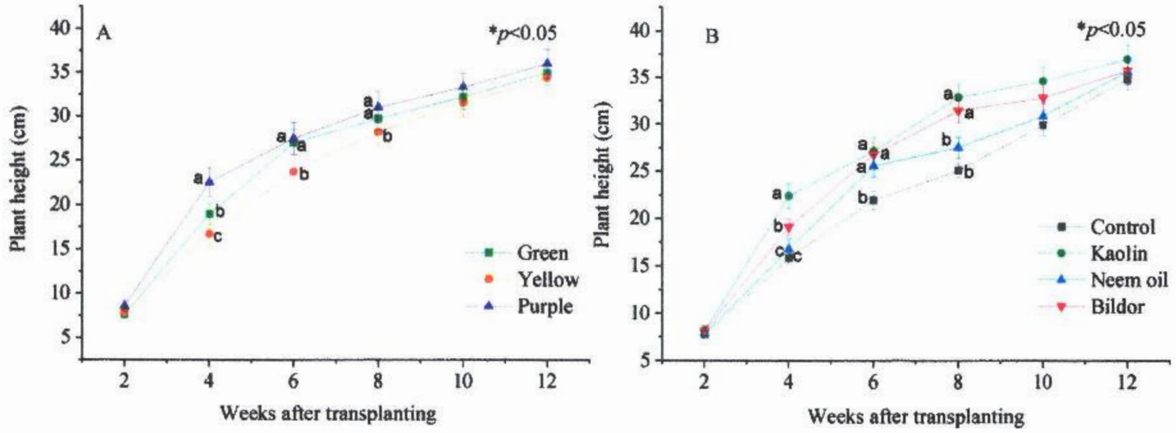

Fig.4.1.2. Effect of capsicum colors and applications on leaf number.

Means of same letters within each column do not differ significantly and Tukey's HSD test at $p < 0.05$ for multiple comparison, p-value indicates level of significance, WAT-Week after transplanting, kaolin was applied at 56 kg ha^{-1} as foliar sprays, neem oil was applied at 2 ml L^{-1}, and chemical (Bildor) was applied 2.5 ml L^{-1}.

4.1.3 number of leaves

There was highly significant variation of leaf number per plant observed due to variation of capsicum colors and applications (Table 4.3). Purple color capsicum plants were produced more leaf per plant compared to yellow and green color producing capsicum plants throughout the growing period. Generally, kaolin and chemical treated plants produced more leaves compared to control and neem oil treated plants. Applications had no significant effect at 2 and 12 WAT.

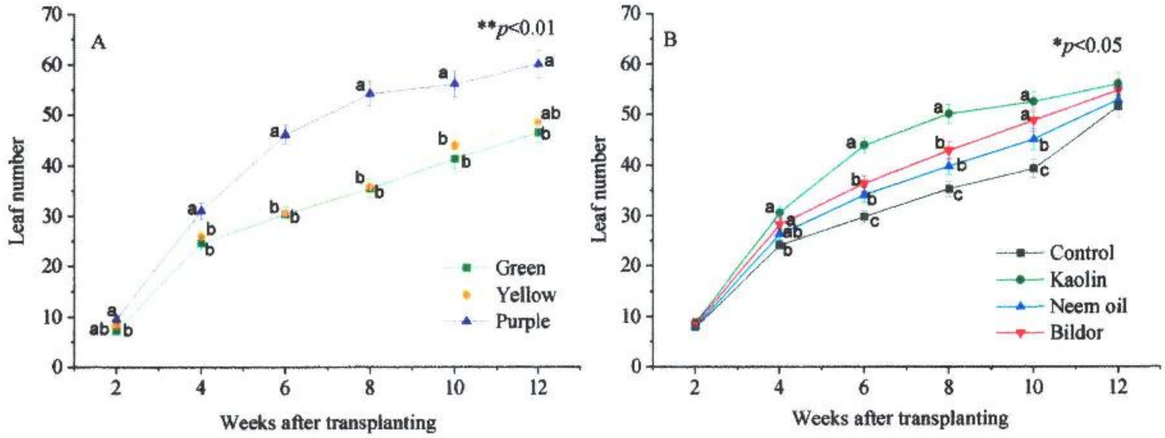

Fig.4.1.3. Effect of capsicum colors and applications on leaf number

Means of same letters within each column do not differ significantly and Tukey's HSD test at $p < 0.05$ for multiple comparison, p-value indicates level of significance, WAT-Week after transplanting, kaolin was applied at 56 kg ha^{-1} as foliar sprays, neem oil was applied at 2 ml L^{-1}, and chemical (Bildor) was applied 2.5 ml L^{-1}.

4.1.4 Days required to first and 50% flowering

Different capsicum colors had significant effect on duration of flower formation as described in Table 4.4. The response of applications to days required to first and fifty percentage flowers were significant. Purple color producing capsicum plants took less time for first and fifty percent flowering compared to yellow and green color capsicum producing plants.

Kaolin treated plants took less time (≥4 days) for flowering than control plants. Similarly, kaolin treated plants took less time for flowering than chemical, neem oil and control plants

4.1.5 SPAD

However, a significant variation on SPAD value and chlorophyll content were documented due to capsicum color differences. Green and yellow color capsicum producing plants were more greenish in appearance than purple color producing plants that was reflected in SPAD value and chlorophyll content of leaf. Also, applications had a significant effect on SPAD value and chlorophyll content. In general, treated plants exhibited better chlorophyll contentment than untreated plants (control).

Table 4.2. Effect of capsicum colors and applications on days required to first and 50% flowering, SPAD value and chlorophyll content.

Treatments	Days required to first flower	Days required to 50% flower	SPAD value		Chlorophyl content (mg/g)	
			4 WAT	6 WAT	4 WAT	6 WAT
Capsicum colors (A)						
Green	26.16 a	32.00 a	52.41 a	57.40 a	6.89 a	7.23 a
Yellow	25.17 a	31.50 a	48.77 a	52.94 a	5.10 a	5.82 a
Purple	22.25 b	26.17 b	39.80 b	44.57 b	4.02 b	4.76 b
Applications (B)						
Control	27.03 a	32.02 a	37.97 b	40.20 b	3.67 b	3.93 b
Kaolin	21.87 b	28.19 b	46.64 a	50.73 a	5.60 a	6.07 a
Neem oil	26.12 a	31.68 a	50.70 a	56.57 a	6.50 a	7.03 a
Bildor	25.66 a	31.34 a	45.66 a	50.04 a	4.81 a	5.69 a
Significance level (p-value)						
A	0.03	0.0004	0.0003	0.002	0.03	0.02
B	0.02	0.01	0.04	0.02	0.04	0.05
A × B	0.65	0.15	0.30	0.50	0.61	0.32

Means of same letters within each column do not differ significantly and Tukey's HSD test at $p < 0.05$ for multiple comparison, p-value indicates level of significance, WAT-Week after transplanting, kaolin was applied at 56 kg ha^{-1} as foliar sprays, neem oil was applied at 2 ml L^{-1}, and chemical (Bildor) was applied 2.5 ml L^{-1}.

4.1.6 Incidence of thrips

The studied factor capsicum colors had no statistically stringent impact on thrips incidence and thrips count while a statistically significant variation was noticed among the applications (Tables 4.5 and 4.6). Kaolin application showed better results for controlling thrips in capsicum production. Kaolin application was reduced significantly thrips infestation by 73.76% compared to control plants. Chemical control was performed better to control thrips too at 6 and 8 WAT. The highest incidence was noticed in untreated plants (control) followed by neem oil treated plants. The applications had no significant effect on thrips incidence and thrips count at 10 and 12 WAT.

Table 4.3. Effect of capsicum colors and applications on thrips incidence.

Treatments	Thrips incidence (%)					
	2 WAT	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT
Capsicum colors (A)						
Green	8.33	8.12	7.29	4.17	4.16	4.13
Yellow	7.29	7.15	6.25	4.17	3.08	4.02
Purple	6.25	6.17	5.94	3.13	2.67	3.11
Applications (B)						
Control	9.72 a	11.11 a	8.33 a	5.56 a	4.16	4.69
Kaolin	4.05 c	2.38 c	1.29 b	1.39 b	2.89	2.95
Neem oil	6.94 b	8.33 ab	6.94 a	5.45 a	4.16	4.19
Bildor	6.83 b	7. 16 ab	2.78 b	2.17 b	3.02	3.56
Significance level (p-value)						
A	0.83	0.31	0.08	0.92	0.43	0.20
B	0.03	0.02	0.05	0.02	0.36	0.74
A × B	0.10	0.23	0.70	0.45	0.52	0.68

Means of same letters within each column do not differ significantly and Tukey's HSD test at $p < 0.05$ for multiple comparison, p-value indicates level of significance, WAT-Week after transplanting, kaolin was applied at 56 kg ha^{-1} as foliar sprays, neem oil was applied at 2 ml L^{-1}, and chemical (Bildor) was applied 2.5 ml L^{-1}.

Table 4.4. Effect of capsicum colors and applications on thrips number.

Treatments	Thrips number					
	2 WAT	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT
Capsicum colors (A)						
Green	0.66	0.67	0.58	0.33	0.33	0.28
Yellow	0.58	0.50	0.50	0.33	0.26	0.25
Purple	0.50	0.46	0.41	0.25	0.18	0.16
Applications (B)						
Control	0.78 a	0.88 a	0.66 a	0.44 a	0.41	0.44
Kaolin	0.32 c	0.11 c	0.10 a	0.13 b	0.15	0.17
Neem oil	0.56 b	0.66 ab	0.55 a	0.42 a	0.39	0.40
Bildor	0.52 b	0.45 ab	0.22 b	0.22 b	0.24	0.27
Significance level (p- value)						
A	0.83	0.31	0.08	0.92	0.43	0.20
B	0.03	0.02	0.05	0.02	0.36	0.74
A × B	0.10	0.23	0.70	0.45	0.52	0.68

Means of same letters within each column do not differ significantly and Tukey's HSD test at $p < 0.05$ for multiple comparison, p-value indicates level of significance, WAT-Week after transplanting, kaolin was applied at 56 kg ha^{-1} as foliar sprays, neem oil was applied at 2 ml L^{-1}, and chemical (Bildor) was applied 2.5 ml L^{-1}.

4.1.7 Number of thrips and yield

There was a significant difference on total number of marketable fruits of capsicum was observed due to different colors (Table 4.7). Purple color gave better number of marketable fruits compared to yellow and green color. However, interaction effect of capsicum color and applications were significant in respect to total yield. The combination of purple color and kaolin application exhibited better results compared to other combination. The green color producing untreated plants (control) showed least results.

Table 4.5. Effect of capsicum colors and applications on fruit number and total yield.

Treatments	Total number of fruits (ha^{-1})	Total yield ($t\ ha^{-1}$)		
Capsicum colors (A)				
Green	2,91,146 b	-		
Yellow	3,36,979 b	-		
Purple	5,56,771 a	-		
Applications (B)		Green	Yellow	Purple
Control	319444	16.12 d	22.12 c	29.27 b
Kaolin	430556	26.04 b	32.91 b	44.86 a
Neem oil	411111	23.77 bc	29.72 b	29.98 b
Bildor	418750	24.84 bc	29.80 b	31.23 b
Significance level (p-value)				
A	0.001		0.08	
B	0.42		0.13	
A × B	0.32		0.04	

Means of same letters within each column do not differ significantly and Tukey's HSD test at $p < 0.05$ for multiple comparison, p-value indicates level of significance, WAT-Week after transplanting, kaolin was applied at 56 kg ha^{-1} as foliar sprays, neem oil was applied at 2 ml L^{-1}, and chemical (Bildor) was applied 2.5 ml L^{-1}.

4.1.8 Correlation

The Pearson correlation matrix revealed that between canopy temperature and thrips incidence had a close relationship with one another (Table 4.8). The correlation was non-significant for all the cases except at 8 and 10 WAT. At 8 WAT, a positive significant association of temperature and thrips incidence were noticed. Although at 10 WAT, the correlation was negative. At later stage of the experiment, the thrips incidence was lower compared to initial incidence.

Table 4.6. The Pearson correlation matrix of canopy temperature and thrips incidence.

	Tm1	Tm2	Tm3	Tm4	Tm5	Tm6	Ic1	Ic2	Ic3	Ic4	Ic5	Ic6
Tm1	1											
Tm2	0.202	1										
Tm3	0.117	0.099	1									
Tm4	0.013	0.015	-0.022	1								
Tm5	0.122	0.142	-0.082	-0.156	1							
Tm6	0.226	-0.005	0.151	0.121	-0.118	1						
Ic1	0.015	-0.119	-0.168	-0.158	0.137	0.003	1					
Ic2	0.212	0.184	0.153	0.424**	-0.327*	0.103	-0.033	1				
Ic3	0.299	0.160	-0.103	-0.123	0.217	-0.075	0.138	-0.085	1			
Ic4	0.057	0.214	0.195	-0.084	-0.142	-0.044	0.257	0.203	-0.205	1		
Ic5	-0.076	-0.027	-0.104	-0.079	0.259	-0.089	0.169	-0.151	-0.303*	0.091	1	
Ic6	0.136	0.107	0.134	-0.127	-0.076	-0.071	0.246	0.145	-0.448**	-0.098	-0.163	1

Tm1= canopy temperature at 2 WAT, Tm2= canopy temperature at 4 WAT, Tm3= canopy temperature at 6 WAT, Tm4= canopy temperature at 8 WAT, Tm5= canopy temperature at 10 WAT, Tm6= canopy temperature at 12 WAT, Ic1= Thrips incidence at 2 WAT, Ic2= Thrips incidence at 4 WAT, Ic3= Thrips incidence at 6 WAT, Ic4= Thrips incidence at 8 WAT, Ic5= Thrips incidence at 10 WAT, Ic6= Thrips incidence at 12 WAT, **,* Significant at $p < 0.01$ and $p < 0.05$.

4.2 Economic evaluation of capsicum production by partial budgeting

4.2.1 Total yield and gross yield

Total marketable yield and price value were higher in pink color plus kaolin combination compared to the pink color plus chemical (Table 4.9). The pink color plus kaolin application system (PK) reduced significant operating cost required for pesticides, labors for spraying and weeding etc. (Table4.9). The cost of production of PK system required about 39.3 % of less operating cost (81,828 Tk. ha^{-1}) than that of traditional capsicum production system (TS) (Table 4.10). However, the cost increases in PK system were 24000, 3000, 5,400 and 6000 Tk. ha^{-1} for plastic mulch, kaolin, labor for mulching set up and harvesting, respectively.

Table 4.7. Total yield, and price variation of following purple color with kaolin clay system (PK) relative to traditional capsicum production system (TS) at Khulna.

Treatments	Total yield (kg ha^{-1})	Value[a] (BDT ha^{-1})
Pink + kaolin	44,860	1,13,72,000
Pink + Chemical	31,230	87,46,000
Changes	13,630	26,26,000

[a]The growers selling price of capsicum were varied from 200-300 Tk. kg^{-1} during the harvesting period.

Table 4.8. Cost comparison between capsicum following traditional system (TS) and purple color with kaolin system (PK).

Cost category	Cost items (BDT/ac)	Total cost of cultivate capsicum in TS (Tk. ha^{-1})	Total cost of cultivation for PK (Tk. ha^{-1})	Total changes in cost due to cultivation of PK (Tk. ha^{-1})
Operating	Plastic mulch[a]	-	24,000	24,000
	Kaolin[b]	-	3,000	3,000
	Pesticide and fungicide cost[c]	5,928	-	-5,928
	Labor cost for mulching set up above beds[d]	-	5,400	5,400
	Labor cost for spraying kaolin, fungicides and pesticides[e]	27,000	16,200	-10,800
	Labor cost for weeding[f]	1,21,500	18,000	-1,03,500
Total operating		1,54,428	66,600	-87,828
Harvesting	Labor for harvesting[g]	54,000	60,000	6,000
Total		2,08,428	1,26,600	-81,828

Cost details (ha^{-1})

[a]Plastic mulch cost 24,000 Tk. (1 roll 8,000 Tk.)
[b]Kaolin cost: 3000 Tk. for PK system (1 bags (11.5 kg) Kaolin 4500 Tk.), [c]Pesticides and fungicides cost: 5928 Tk. for traditional system (TS),
[d]Labor cost for mulching set up at 450 Tk. $labor^{-1}$ (12 labors)
[e]Labor cost for spraying: 20 times for TS and 12 times for PK system at 450 Tk. $spray^{-1}$, 3 labors $spray^{-1}$
[f]Labor cost for weeding: at 450 Tk. $labor^{-1}$ - 6 times for TS (45 labors each time) and 4 times for L02 (10 labors each time),
[g]Labor cost for harvesting: at 200 Tk. $person^{-1}$, 10 times harvesting (30 labors each time) for PK system and 9 times harvesting (30 labor each time) for TS system.

4.2.2 Marketable yield and cost of production

The marketable fruit yield of PK system was 44,860 kg ha^{-1}, and similarly marketable yield of TS was 31,230 kg ha^{-1}. Purple plus kaolin application system yield was increased by 13,630 kg ha^{-1}over TS (Table 4.9). During growing period capsicum growers having prices for capsicum were varied from 200 to 300 Tk. (DNCRP, 2021). The expected net profit from the cultivation of purple capsicum plus kaolin application was 27,07,828 Tk. ha^{-1} would be greater than cultivating capsicum in traditional way, signifying increased effectiveness potential under this specific set of assumptions (Table 4.11).

Table 4.9. Changes in return in cultivating purple color capsicum with kaolin clay relative to Traditional system.

Budget variable	Total fruit yield changes (kg ha^{-1})	Value changes (Tk.)
Yield (kg)	13,630	26,26,000
Cost (Tk.)	-	81,828
Total return (Tk.)	-	27,07,828

4.3 Discussion

Improved plant vigor of kaolin-treated strawberry transplants is consistent with previous reports that kaolin can protect plants against heat stress. Application of a kaolin clay suspension was reported to have resulted in a white coating that reflected light and maintained cooler temperatures on treated as opposed to untreated leaves on tomato plants (Cantore et al. 2009). According to Cantore et al. (2009), kaolin aids in reducing the loss of water from the plant from transpiration and increases the drought tolerance of the plant. Boari et al. (2015) observed that the antitranspirant effect of kaolin promotes transplant establishment under adverse conditions. In the present study, kaolin created a white layer on the foliage and the surface of the black plastic mulch. As a result, the leaves and mulch would have reflected the incoming solar radiation and kept the plants cool. It is likely that transpiration was reduced with the kaolin applications, allowing the plants to resist dehydration. The microenvironment around the plants may have also been cooler with the kaolin treatments, which may explain the improvement in plant vigor. Also, the white layers adhering to the leaf surface causing irritation for insects and helps to eliminate their scavenging activity on the leaves and fruits of crops. This clay suspension helps to repel different type of insects like thrips, mites, beetles, leaf roller etc. and supports plants to grow more vigorously (Glenn, 2012). Application kaolin to crops of all sorts has been shown to be an effective way to decrease negative environmental influences, prevent disease and deter many kinds of insect pests (Anonymous, 2018.). Kaolin treated pepper plants showed better efficacy against western flower thrips (*Frankliniella occidentalis*), Florida flower thrips (*F. bispinosa*), and eastern flower thrips (*F. tritici*) in a field trial in Florida reported by Funderburk (2014). Both the preventive and curative kaolin applications caused a significant decrease in the populations of thrips (*E. vitis* and *Z. rhamni)* nymphs (Tacoli, et al., 2017). Chemicals dominated over botanicals and acetamiprid at 0.004% reduced 93.3% thrips population on chili reported by Mandi and Senapati (2009). Additionally, ultineem at 1% (Botanical) showed better performance and control 54.2% thrips population. Similar types of findings were stated by Patel and Kumar (2017). They mentioned that the chemicals Spinosad at 0.2 ml/l was recorded highest control of thrips (79.79%).

The chlorophyll content of leaves infested by thrips lower than non-infected leaves. To get the nutrients thrips stick into the leaf tissue and suck the liquid epidermis, palisade containing chlorophyll and mesophyll cells (Kirk, 1997). Kolb et al. (1991) rereporting five adult thrips per bud in confinement will cause chlorosis. Damage caused by feeding thrips cause high loss water rate. Leaves infested by thrips tend to experience water stress and reduce the rate of photosynthesis in conditions of low water availability. The kaolin treated plants took less time for flowering because those plants grow vigorously with less thrips infestation causing early flowering. However, the purple color performed better than other colors in respect of growth and development parameters may be a genetic cause. High densities of thrips cause retarded plant growth (Kawai, 1986).

Weather variables including temperature, relative humidity and rainfall have been reported as important factors that significantly affect the thrips population (Waiganjo et al., 2008). In addition to their effect on thrips activity, temperature and relative humidity further influence the intrinsic rate of natural increase of thrips (Murai, 2000). Our results are in partial agreement with Fathi et al. (2011) who reported that there was 40 to 90 % survival of nymphs on different canola cultivars at 25°C. Murai (2000) reported 67.5 % survival both at 25 and 30°C on pollen and honey solution cultivars. Our findings are not in line with Kumar (2013) who revealed that at an average temperature of 34.17°C, there was 75 % survival and at an average temperature of 31.43°C, the survival of nymphs was 89 % in the cotton plant. Environmental conditions such as temperature and light are known to modulate plant–insect interactions (Escobar-Bravo, et al., 2018, Wang, et al., 2009; Zavala, et al., 2015). The difference in observations may be due to differences in environmental conditions.

The efficacy of insecticides studied in the present experiment is reported by many authors in green chilli and capsicum and the present results are in agreement with the reports by Roopa (2013) who reported that lowest populations, highest per cent reduction of thrips was recorded with the treatment Spinosad 45 SC @ 0.01% in capsicum and it also resulted in maximum fruit yield (30.05 tha^{-1}). Similarly, Vanisree et al. (2017) reported that Spinosad 0.015% was found most effective in reducing the population of thrips as well as in increasing yields in chilli and it attains highest cost benefit ratio. Consistent with our results, kaolin-treated tomato plants had larger fruit and higher total crop yield (Cantore et al., 2009) and total yield was increased in kaolin-treated pepper plants (Makus 2005). Kaolin also does not appear to have any recorded negative effects on horticultural crops. Kaolin-treated grape vines exhibited no negative impacts from kaolin with respect to cluster size and weight of clusters (Shellie and Glenn, 2010). Williams et al. (2011) reported that extreme damaged by thrips can result in yield loss in capsicum. Several thrips' species contributed to yield losses in capsicum (Cannon, et al., 2007; Ssemwogerere, et al., 2013; Walsh, et al., 2012; Weintraub, 2007). Similar yield loss trend was noticed in the present experiment where untreated plants were more thrips infestation led to yield loss. However, the profits incentive was offered by price premiums from more capsicum yield. The savings in inputs costs would increase more to this cost-efficacy.

Though insecticides are found be the most promising tools of insect pest management, there is a need to integrate other safe methods of pest management to overcome the negative effects of insecticides. Now-a-days kaolin clay is the most widely used organic clay particles for the agricultural insect pests and have been particularly important in surveillance and monitoring of the seasonal appearance of many species.

CHAPTER VI

SUMMARY AND CONCLUSION

Capsicum is one of the high value horticultural crops grown extensively throughout the world, especially for its taste, nutritional enrichment and attractive color. One of the major problems of capsicum cultivation is thrips infestation throughout the cultivation period. Kaolin is an organic mineral compound rich in kaolinite was widespread use to reduce insect infestation in various crops. From the study, it is found that growth, yield components of capsicum yield and net profitability were highly influenced by different capsicum colors and applications. It was found that higher marketable total yield (44.86 tha^{-1}) resulted from purple color plus kaolin application combination than green color with no application (control) (16.12 tha^{-1}). Flowering occurred earlier by more than 4 days in plants on treated with kaolin compared to the untreated plants (control). In addition, kaolin application was lowered thrips infestation by 73.76% than control plants. The total effectiveness of capsicum production was raised by Tk. 27,07,828 ha^{-1}. Therefore, pink color genotype with kaolin application for controlling thrips in field condition came up with a new hope for vegetable growers in Bangladesh that would ensure maximum economic returns.

CHAPTER VII

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Appendix I

Research activities at Khulna University at a Glance (2020-2021)

Fig. 1. The capsicum field initially treated with treated with Kaolin clay and visited by the PI of the project.

Fig. 2. SPAD value measurement to check greenness of capsicum leaf.

Fig. 3. Canopy temperature measurement

Fig. 4. Capsicum fruiting was started in the field.

Fig. 5. Weighing of capsicum in the field after harvest.

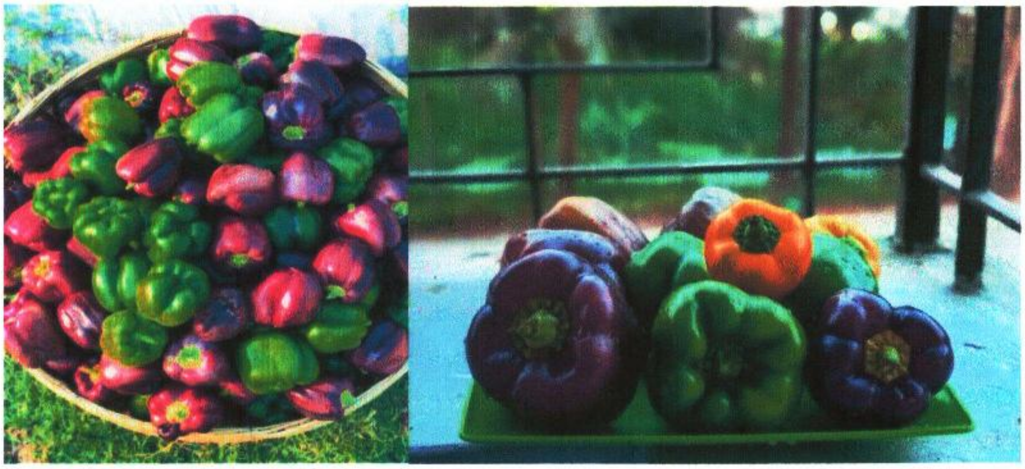

Fig. 6. Colorful capsicum after harvest.