EFFECT OF PEST EXCLUSION NET AND MULCHING ON OKRA PRODUCTION AT RAMPUR, CHITWAN, NEPAL

SWASTIKA CHAUHAN

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF PEST EXCLUSION NET AND MULCHING ON OKRA PRODUCTION AT RAMPUR CHITWAN"** submitted in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture (Horticulture)** of the Agriculture and Forestry University, Chitwan, Nepal is a record of original research carried out by **Mrs. SWASTIKA CHAUHAN, Id. No. HRT-14M-2016,** under my supervision, and no part of thesis has been submitted for any other degree or diploma.

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This thesis attached herewith, entitled **“EFFECT OF PEST EXCLUSION NET AND MULCHING ON OKRA PRODUCTION AT RAMPUR CHITWAN”** prepared and submitted by **Mrs. SWASTIKA CHAUHAN,** in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture (Horticulture),** is hereby accepted.

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DEDICATED TO MY BELOVED PARENTS

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Swastika Chauhan

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ACRONYMS

%	: Percent
°C	: Degree Celsius
µ	: Micron
AFU	: Agriculture and Forestry University
AICC	: Agriculture Information and Communication Center
ANOVA	: Analysis of Variance
Asst.	: Assistant
AVRDC	: Asian Vegetable Research and Development Center
B.S.	: Bikram Samwat
B:C	: Benefit Cost
cm	: Centimeter
CV	: Coefficient of Variation
DAP	: Diammonium Phosphate
DAT	: Days After Transplanting
DMRT	: Duncan's Multiple Range Test
FAO	: Food and Agriculture Organization
GDD	: Growing degree days
gm	: Gram
HDPE	: High Density Polyethylene
IPM	: Integrated Pest Management
Kcal	: Kilo Calorie
kg	: Kilo Gram
KJ	: Kilo Joule
LDPE	: Low Density Polyethylene
LSD	: Least Significant Difference
m	: Meter
cm	: Centimeter
mm	: Millimeter
MoAD	: Ministry of Agricultural Development
MOP	: Muriate of potash
NS	: Not Significant
NUE	: Nitrogen Use Efficiency

PAR	: Photo-synthetically active radiation
SEM	: Standard Error of Mean
Wt	: Weight
WUE	: Water Use Efficiency

ABSTRACT

Name: Swastika Chauhan **Id. No.: HRT-14M-2016**
Semester and Year of Admission: 2016 **Degree: M.Sc.Ag.**
Major Advisor: Prof. Arjun Kumar Shrestha, PhD **Department: Department of Horticulture**

This study entitled 'Effect of Pest Exclusion Net and Mulching on Okra Production at Rampur, Chitwan, Nepal' was conducted at Horticulture Farm of Agriculture and Forestry University, Rampur, Chitwan, Nepal from May, 2018 to August, 2018. The experiment was laid out in a randomized complete block design having five treatments namely i) Control (No net + no mulch) ii) Organic mulch (Rice straw mulch) iii) Black plastic mulch iv) Silver plastic mulch v) Pest exclusion net + black plastic mulch. Swastik-2 F1 variety was selected for the study. Recorded data were analyzed using R-software (R version 3.5.3), MS Excel 2016 and Minitab 18. The result revealed that silver plastic mulch and black plastic mulch treatment resulted in significantly higher yield (30.74 and 29.39 mt/ha respectively), leaf number per plant (27.98 and 26.73), branch number per plant (5.1 and 4.8), fruit number per plant (33.65, 29.77) and the lowest days to flowering (38.5 and 39.75 days) while PEN+black plastic mulching treatment resulted in higher stem diameter (25.41 mm), higher plant height (212.93 cm), longest days to flowering (43 days), higher fruit length (18.26 cm), higher fruit diameter (17.34 mm), higher fruit weight (32.80 gm) , the lowest leaf number per plant (15.58), the lowest branch number per plant (3.85), the lowest yield (20.4 mt/ha) and the lowest light intensity (110.32 lux). There was no significant difference in yield between black plastic mulching and silver plastic mulching. Correlation study on yield attributing factors also revealed that yield of okra is positively and significantly correlated with leaf number per plant (0.984), branch number per plant (0.962), fruit number per plant (0.972) and soil temperature (0.899). Similarly, days to flowering was found negatively and significantly correlated with yield (-0.985) of okra. Plant inside PEN+black plastic mulching which received low light intensity had higher vegetative growth but found with low yield. Plant in control and straw mulch treatment were found with both low vegetative growth and yield. The cultivation with silver plastic mulch and black plastic mulch were economically more viable as compared to other treatments. in Chitwan.

Prof. Arjun Kumar Shrestha, PhD
Major Advisor

Swastika Chauhan
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शोध-सार

नामः स्वस्तिका चौहान

परिचय पत्र नं.: HRT-14M-2016

सत्र तथा भर्ना वर्षः प्रथम, सन् २०१६

उपाधीः एम.एस्सी. कृषि

मुख्य विषयः वागवानी

विभागः वागवानी विभाग

मुख्य सल्लाहकारः प्रा. डा. अर्जुन कुमार श्रेष्ठ

"रामपुर, चितवनमा लगाईएको भिण्डीको उत्पादनमा जालि घर र छापोको प्रभाव" शिर्षक अन्तर्गत चितवन स्थित कृषि तथा वन विज्ञान विश्वविद्यालय, रामपुर स्थित वागवानी फार्ममा सन् २०१८ मे देखी २०१८ अगास्टसम्म यस अध्ययन गरिएको थियो। यस अनुसन्धानमा पाँच वटा उपचारहरु जस्तै क) कन्ट्रोल (छापो र जाली दुबै नभएको), ख) प्राङ्गारिक छापो (परालको छापो) ग) कालो रङ्गको प्लाष्टिक एकातर्फ कालो र अर्कोतर्फ चाँदी रङ्ग भएको छापो घ) चाँदी रङ्गको प्लाष्टिक एकातर्फ चाँदी र अर्कोतर्फ कालो रङ्ग भएको छापो ङ) जालीघरभित्र कालो रङ्गको प्लाष्टिक छापो लाई चार पटक दोहोर्‍याई सहितको रेन्डमाईज कम्प्लिट ब्लक डिजाईनमा गरिएको थियो।अध्ययनका लागि स्वस्तिक-२ एफ १ जात छनौट गरिएको थियो। अध्ययनमा प्राप्त तथ्याङ्कहरुलाई आर सफ्ट्वयर, एक्सेल २०१६ र मिनिट्याव १८ को माध्यमबाट विश्लेषण गरिएको थियो। प्राप्त नतिजाअनुसार चाँदी रङ्गको प्लाष्टिक र कालो रङ्गको प्लाष्टिक छाप प्रयोग गर्दा भिण्डीको उत्पादकत्व (३०.७४ टन/हे. र २९.३९ टन/हे.), पात संख्या प्रति बोट (२७.९८ र २६.७३), हाँगा संख्या प्रति बोट (५.१ र ४.८), भिण्डी फल संख्या (३३.६५ र २९.७७) उल्लेखिनय रुपमा धेरै पाईएको थियो र फूल फूल्न आवश्यक दिनहरु (३८.५ र ३९.७५ दिनहरु) अन्यन्त न्यून पाईयो। जबकि जालीघरभित्र कालो रङ्गको प्लाष्टिक छापो उपचारमा डाँठको व्यास (२५.४१ एम.एम.), बोटको उचाई (२१२.९३ से.मी.), फूल फूल्न आवश्यक दिनहरु (४३ दिनहरु), फलको लम्बाई (१८.२६ से.मी.), फलको व्यास (१७.३४ एम.एम.), फलको तौल (३२.८० ग्राम) अधिक पाईएको थियो भने पात संख्या प्रति बोट (१५.५८), हाँगा संख्या (३.८५), उत्पादकत्व (२०.४ टन/हे.) र प्रकाश तिव्रता (११०.३२ लक्स) न्यून पाईएको थियो।कालो रङ्गको प्लाष्टिक छापो र चाँदी रङ्गको प्लाष्टिक छापो बीच भिण्डीको उत्पादकत्वमा कुनै उल्लेखिनय भिन्नता पाईएन। उत्पादकत्वसँग सम्बन्धित

तत्वहरुको सहसम्बन्ध अध्ययन गर्दा, भिण्डीको उत्पादकत्व पात संख्या (०.९८४), हाँगा संख्या प्रति बोट (०.९६२), फल संख्या प्रति बोट (०.९७२) र माटोको तापक्रम (०.८९९) सँग सकारात्मक एवं उल्लेखिनय तवरले सहसम्बन्ध रहेको पाईयो। प्रकाश तिव्रताको पनि उत्पादकत्वसँग अधिकरुपमा सकरात्मक सहसम्बन्ध (०.७७७) रहेको पाईयो। त्यसैगरी, फूल फूल्न लाग्ने दिनहरु र भिण्डीको उत्पादकत्व बीचको सहसम्बन्ध नकारात्मक तवरले उल्लेखिनय सहसम्बन्ध (-०.९८५) रहेको पाईयो। जालीघर भित्र कालो रङ्गको प्लाष्टिक छापोमा रहेका बोटहरु जसले न्यून प्रकाश तिव्रता प्राप्त गरेका छन्, तिनीहरुको वानस्तपतिक वृद्धि राम्रो भएको तर उत्पादकत्व कम भएको पाईयो। कन्ट्रोल र परालको छापो उपचारमा रहेका बोटहरुमा भने न्यून वानास्पतिक वृद्धि र न्यून उत्पादकत्व रहेको पाईयो।फाईदा-लागतको अनुपातले अरु उपचार पद्दती भन्दा चाँदी रङ्गको प्लाष्टिक छापो र कालो रङ्गको प्लाष्टिक छापोमा भिण्डी खेती गर्दा आर्थिक हिसावले व्यवहार्य देखायो। तसर्थ, यस अध्ययनले भिण्डी खेती गर्दा उच्चतम उत्पादनका लागि चाँदी रङ्गको प्लाष्टिक छापो र कालो रङ्गको प्लाष्टिक छापो नै चितवनमा उपयुक्त हुने देखायो।

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1 INTRODUCTION

1.1 Background information

Okra [*Abelmoschus esculentus* (L.) Moench] is the only vegetable crop of significance in the Malvaceae family and is very popular in the South-Asian Countries. In Nepal, it is widely cultivated in hilly and terai region for the vegetable purpose but its original home is Ethiopia and Sudan, the north-eastern African countries (Mahadeen, 2014). It is one of the oldest cultivated crops (Lamont, 1999). It is presently grown in many countries and is widely distributed from Africa to Asia, southern Europe and America. It is a tropical to subtropical crop and is sensitive to frost; low temperature, water logging and drought conditions. Different countries have adapted certain distinguishing characteristics specific to the country to which they belong.

Climate change and its accompanying environmental stress will consequently lower crop productivity especially in developing countries where crop production is mainly rainfed (Bray, Bailey-Serres, Weretilnyk, Buchannan, & Jones, 2000). Unpredictable drought and high temperatures during the growing season are key environmental challenges affecting crop productivity and food security worldwide (Dubois, 2011).

Water deficit is one of the most-environmental stresses that affects the agricultural productivity in much of the world (Wang & Frei, 2011) and may result in considerable growth and yield reductions. Nepal ranks world's second richest country in terms of water resources. However, irrigation facilities is for only 33.79% of the cultivable land, while 66.21% of the land is rain-fed (MoAD, 2016).

The mountains in the north act as barrier to the cold winds blowing from Central Asia during winter, and create the northern boundary for monsoon rains. Some locations like Manang and Mustang fall in the rain shadow behind the mountains and are almost dry. Annual precipitation of Nepal is 1600 mm but it varies by eco-climatic zones, such as 3,345 mm annual rainfall in Pokhara and below 300 mm in Mustang ("Climate of Nepal," 2020). Nearly eighty percent of all the rain in Nepal is received during the monsoon (June-September). Winter rains are more pronounced in the western hills ("Climate of Nepal," 2020). Therefore, in most of the areas lacking of regular irrigation, soil moisture is generally limited and crop growth is stressed by drought during summer growing season, resulting in decreased and unsustainable crop yields. The short period rainfall during rainy season has led vegetables rely on stored soil moisture. Water use efficiency of dry matter production can be increased in different ways but chiefly by decreasing evaporation from the soil surface.

In recent years, the use of polyethylene mulch in vegetable production is being a topic of interest to the farmers. Mulching practices cum protected horticulture practice may be more effective technique for vegetable farming, which could be introduced in the production of vegetables during summer. Mulching helps to reduce the deterioration of soil by way of preventing runoff and soil loss, minimizes weed infestation and reduces water evaporation. Thus, it facilitates more retention of soil moisture and helps in control of temperature fluctuations, improves physical, chemical and biological properties of soil and ultimately enhances the growth and yield of crops (Muhammed, 2015).

Black plastic mulch is the standard plastic mulch used in vegetable production in Nepal. Worldwide, the increased usage of plastic mulch is due to its benefits when applied in the field, i.e. increases soil temperature, especially in early spring, reduces weed problems, enhances moisture conservation, increases crop yields and leads to more efficient use of soil nutrients (Ban, Žanić, Dumičić, Čuljak, & Ban, 2009; Hatami, Nourjou, Henareh, & Pourakbar, 2012; Kwabiah, 2004; Mamkagh, Salmerón, García, & Real, 2009). Mulching with black plastic prevents sunlight from reaching the soil surface which reduces weed growth and promotes soil warming and early crop establishment (Schonbeck, 2015).

The use of plastic mulch has been reported to conserve soil moisture (Kumar & Lal, 2012). Hence, under prevailing drought and water scarcity conditions, conservation of soil moisture and ensuring its availability to agricultural crops are of vital importance. In addition to the positive role of plastic mulch in soil moisture conservation, it inhibits weeds growth as an extra benefit (Hatami et al., 2012; Kumar & Lal, 2012; Mamkagh et al., 2009).

This study aimed to investigate the effects of straw mulching, black plastic mulching, silver plastic mulching and mulching inside PEN house on okra.

1.2 Objectives

General objective

- To improve the yield of okra through mulching and pest exclusion net.

Specific objectives

- To find out the effects of different mulching techniques on growth and yield attributing traits of okra
- To determine the effects of pest exclusion net on growth and yield of okra

2 LITERATURE REVIEW

2.1 Origin and distribution

It is believed that okra is originated from Ethiopia and Sudan, the north-eastern African countries (Chanchal et al., 2018; Mahadeen, 2014). However, some scientists argue that one putative ancestor (*Abelmoschus tuberculatus*) is native from Northern India, suggesting that the species originated from this geographic area. *Abelmuschus esculentus* is found all around the world from Mediterranean to equatorial areas as may be seen from the geographical distribution of cultivated and wild species as shown in Figure 1 (Tripathi, Warrier, Govila, & Ahuja, 2011).

Taxonomists described about 50 species in the genus *Abelmoschus.* The taxonomical revision undertaken by van Borssum Waalkes (1966) and its continuation by Bates (1968) constitutes the most fully documented studies of the genus *Abelmoschus*. Taking classification of van Borssum Waalkes as the starting point, an up-to-date classification adopted at the International Okra Workshop were as given in Table 1 (Tripathi et al., 2011).

Table 1. Classification in the genus Abelmoschus

SN	Species
1	*A. moschatus* Medikus- subsp. *moschatus* var. *moschatus*- subsp. moschatus var. *betulifolius* (Mast) Hochr- subsp. *Biakensis* (Hochr.) Borss. subsp. *tuberosus* (Span) Borss.
2	*A. manihot* (L.) Medikus- subsp. *tetraphyllus* (Roxb. ex Hornem.) Borss. var. *tetraphyllus* - var. *pungens*
3	*A. esculentus* (L.) Moench
4	*A. tuberculatus* Pal & Singh
5	*A. ficulneus* (L.) W & A.ex. Wight
6	*A. crinitus* Wall.
7	*A. angulosus* Wall. ex. W, & A.
8	*A. caillei* (A. Chev.) Stevels

Out of the above, the first three species are wild and cultivated forms, whereas the remaining are all wild forms.

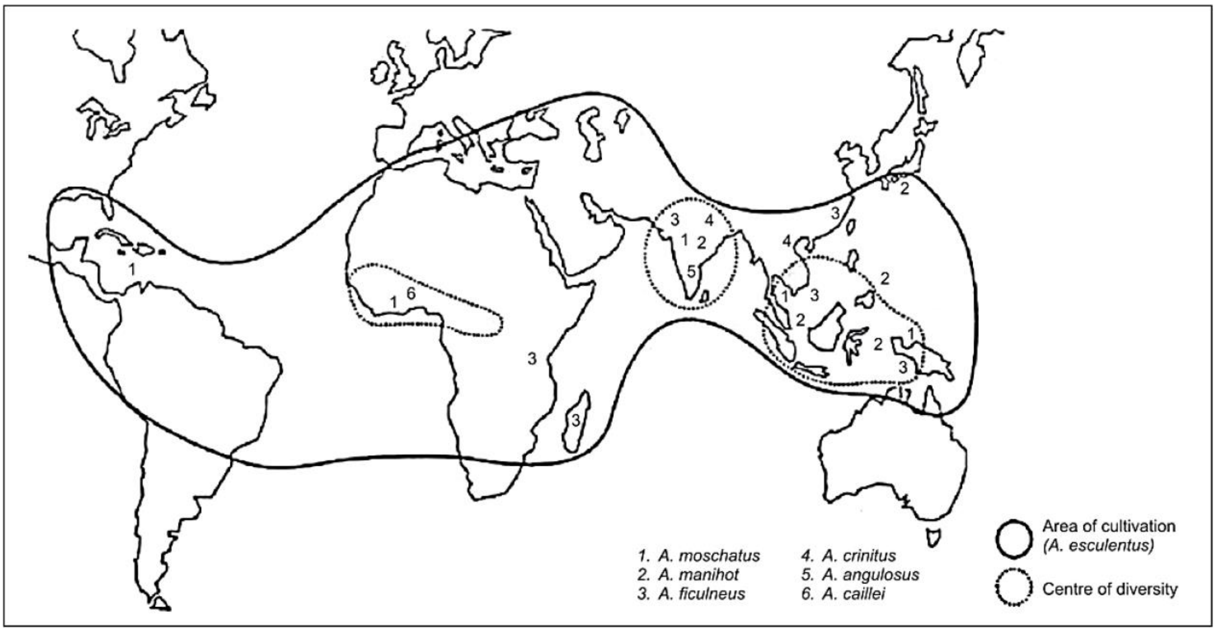


Figure 1. Geographical distribution of *Abelmoschus* species

2.2 Botanical description (Biology of okra)

The chromosome number (2n) of *A. esculentus* L. (Moench) has been variably reported by different authors. The most frequently observed somatic chromosome number, however, is 2n=130, although Datta and Naug (1968) suggest that the numbers 2n=72, 108, 120, 132 and 144 are in regular series of polyploids with n=12. The existing taxonomical classifications at the species level in the genus *Abelmoschus* are unsatisfactory.

Okra is an erect herbaceous plant mainly propagated by seeds and has 90-100 days of growth period. It is generally an annual plant. Its stem is green with or without reddish tinge, robust, variable in branching and varying from 0.5 to 4.0 metres in height (Tripathi et al., 2011). Leaves are alternate and usually palmately five to seven lobed.

The okra flowers are 4-8 cm in diameter, with five white to yellow petals, often with a red or purple spot on the claw and the flower withers within one day. The flower structure combines hermaphroditism and self-compatibility. Flower bud appears in the axil of each leaf, above 6^{th} to 8^{th} leaf depending upon the cultivar. The crown of the stem at this time bears 3-4 underdeveloped flowers but later on during the period of profuse flowering of the plant there may be as many as 10 undeveloped flowers on a single crown. As the stem elongates, the lower most flower buds open into flowers. There may be a period of 2, 3 or more days between the times of development of each flower. A flower bud takes about 22-26 days from initiation to full bloom. The style is surrounded by a staminal column which may bear more than 100 anthers. The pollen may come in contact with the stigmas through a lengthening of the staminal column or through insect foraging (Thakur & Arora, 1986)**.** The pollen grain is large with many pores, and every pore is a potential tube source; therefore, many tubes can develop from one pollen grain (Tripathi et al., 2011). Stigma is 5-9 lobed. Fruit is capsule. Flowers remain open for shorter duration and wither in the afternoon. The stigma is receptive during anthesis; hence pollination is not very successful at bud stage. It is basically a self–pollinated crop, however, cross–pollination through insects can be as high as 19%. Hence okra is classified as often-cross pollinated vegetable crop (Tripathi et al., 2011).

Okra plants are characterized by indeterminate growth. Flowering is continuous but highly dependent upon biotic and abiotic stress. The plant usually bears its first flower one to two months after sowing. The fruit is a capsule and grows quickly after flowering. The greatest increase in fruit length, height and diameter occurs during 4^{th} to 6^{th} day after pollination. It is at this stage that fruit is most often plucked or consumption. The pods are ready for harvest in about 45 and 60 days after seed sowing depending upon variety and season (Oli, 2015). The okra pods are harvested when immature and high in mucilage, but before becoming highly fibrous. Generally the fibre production in the fruit starts from 6^{th} day onwards of fruit formation and a sudden increase in fiber content from 9th day is observed (Nath, Velayudhan, & Singh, 1987). Okra plants continue to flower and to fruit for an indefinite time, depending upon the variety, the season and soil moisture and fertility. Infact the regular harvesting stimulates continued fruiting, so much that it may be necessary to harvest every day in climates where growth is especially vigorous.

2.3 Climatic requirements

Okra is a tropical crop. It requires a long, warm and humid growing climate for better yield. It is sensitive to frost and extremely low temperatures. Optimum temperature for okra is 21 to 30^0C, with minimum temperature of 18^0C and maximum temperature of 35^0C (Abd El-Kader, Shaaban, & Abd El-Fattah, 2010). Adjustment of climatic factors helps in taking more than one crop at north Indian plains and almost year-round cultivation under moderate climate in south India. The suitable environment for seed production is low precipitation, low relative humidity and high light intensity with hot and dry conditions during seed ripening (Dhankhar et al., 2012). Solar radiation is a source of providing energy for living organisms and all physiological processes are dependent on photosynthetically active radiation. The optimum condition of input resources is essential for efficient utilization of photosynthetically active radiation absorption, which ultimately influences the crop yield. Temperature, humidity and radiation are major meteorological parameters, which influence all aspects and stages of crop growth. Temperature is a key component of climate, determining the seedling time and consequently the rate and duration of growth and productivity of crop (Pal et al., 2001). Agroclimatic indices i.e., growing degree days, photo thermal and heliothermal units are useful for assessing the agroclimatic resources in crop planning and reflecting the impact of agro meteorological variables at different crop growth stages.

Germination largely depends upon soil temperature and soil moisture content, while emergence depends upon seedbed conditions and the soil strength. Walter (1990) reported that the soil temperature conditions for okra seed germination is optimum in the range of about 21 to 35 °C and the minimum is 15.5 °C and the maximum is 40.5 °C.

Lyons (1973) reported that okra injured when exposed to temperature below 12 °C. Sionit et al., (1981) reported seed germination for okra (Clemson spineless) at 16/11, 20/14 and 23/17 °C day/night temperature, with the lowest temperature delayed the emergence. Marsh (1993) studied the effect of moisture content on the emergence and development of okra seeds and found that high moisture decreased the emergence of okra seeds. Anderson (2012) found that selection of a hybrid that germinates early under favorable temperature and then weeds would not offer competition, is the most efficient method for achieving good establishment.

In the study of Kyriakopoulou et al. (2010) on effect of shading on the growth and yield of okra (*Hibiscus esculentus* L.) under hot, summer conditions in the Mediterranean region, the number of flowers per plant was found unaffected by shading in either cultivar but the total number of pods per plant was obtained decreased under 70% shading leading to a reduction in total pod weight. Overall, it appears that shading of okra plants during cultivation under hot Mediterranean conditions is not beneficial for okra production.

Mulches help to maintain soil moisture content longer than bare soil (Budania & Dahiya, 2018). Mulching conserves water by reducing evaporation and mitigates negative effects of water stress on plant growth and yield under semi-arid conditions. Mulching conserves moisture contents, which in turn results in increase in the plant growth (Nasir, Moazzam, & Shahbaz, 2011).

2.4 Nutritional importance

Okra is a multipurpose crop due to its various uses of the fresh leaves, buds, flowers, pods, stems and seeds. Okra immature fruits, which are consumed as vegetables, can be used in salads, soups and stews, fresh or dried, fried or boiled. It offers mucilaginous consistency after cooking. Often the extract obtained from the fruit is added to different recipes like stews and sauces to increase the consistency. Okra has been called "a perfect villager's vegetable" because of its robust nature, dietary fiber, and distinct seed protein balance of both lysine and tryptophan amino acids (unlike the proteins of cereals and pulses) (Çalışır, Özcan, Hacıseferoğulları, & Yıldız, 2005).

Okra mucilage has medicinal applications when used as a plasma replacement or blood volume expander (Rood & Madison, 2008). The mucilage of okra binds cholesterol and bile acid carrying toxins dumped into it by the liver. Okra seeds are a potential source of oil, with concentrations varying from 20% to 40%, which consists of linoleic acid up to 47.4%. Okra seed oil is also a rich source of linoleic acid, a polyunsaturated fatty acid essential for human nutrition (Habtamu, Negussie, Gulelat, Woldegiorgis, & Fekadu, 2014). It can be also used as non-caffeinated substitute for coffee. Okra seeds may be roasted and ground to form a caffeine-free substitute for coffee (Çalışır et al., 2005).

The amino acid composition of okra seed protein is comparable to that of soybean and the protein efficiency ratio is higher than that of soybean and the amino acid pattern of the protein renders it an adequate supplement to legume or cereal based diets (Adetuyi, Ajala, & Ibrahim, 2019; Oyelade, Ade-Omowaye, & Adeomi, 2003). Okra seed is known to be rich in high quality protein especially with regards to its content of essential amino acids relative to other plant protein sources. Hence, it plays a vital role in the human diet (Farinde, Owolarafe, & Ogungbemi, 2007).

Okra is a powerhouse of valuable nutrients, nearly half of which is soluble fibre in the form of gums and pectins which help to lower serum cholesterol, reducing the risk of heart diseases. The other fraction of Okra is insoluble fibre, which helps to keep the intestinal tract healthy. Okra is also abundant with several carbohydrates, minerals and vitamins, which plays a vital role in human diet and health. Okra is rich in phenolic compounds with important biological properties like quartering and flavonol derivatives, catechin oligomers and hydroxycinnamic derivatives. The composition of okra pods per 100 g edible portion (81% of the product as purchased, ends trimmed) is: water 88.6 g, energy 144.00 kJ (36 kcal), protein 2.10 g, carbohydrate 8.20 g, fat 0.20 g, fibre 1.70 g, Ca 84.00 mg, P 90.00 mg, Fe 1.20 mg, βcarotene 185.00 µg, riboflavin 0.08 mg, thiamin 0.04 mg, niacin 0.60 mg, ascorbic acid 47.00 mg (Habtamu et al., 2014). Okra is also known for being high in antioxidants activity. Okra has several potential health beneficial effects on some of the important human diseases like cardiovascular disease, type 2 diabetes, digestive diseases and some cancers. Overall, okra is an important vegetable crop with a diverse array of nutritional quality and potential health benefits (Habtamu et al., 2014).

2.5 Other importance

Okra is mainly grown for its immature pod that can be used as fried or boiled vegetable, it may be added as soup or salad (Kashif, Yaseen, Arshad, & Ayub, 2008). It is also use as coffee substitute; mature dried seed of okra can be roasted and ground as coffee substitute or added to coffee as an adulterant. Okra leaves are considered good as cattle feed, but this is seldom compatible with the primary use of the plant. The leaf buds and flowers are also edible (Doijode, 2001). Moreover, okra mucilage is suitable for industrial and medicinal applications (Akinyele & Temikotan, 2007). Industrially, okra mucilage is usually used for glace paper production and also has a confectionery use. Okra has found medical application as a plasma replacement or blood volume expander(Lengsfeld, Titgemeyer, Faller, & Hensel, 2004.).

2.6 Irrigation

Irrigation scheduling is considered as an important component of water management to produce higher irrigation efficiency under any irrigation system, as excessive or sub-optimum irrigation both have detrimental effects on productivity parameters of okra (Panigrahi, Sahu, & Pradhan, 2011).

2.7 Mulching effects

Any material that is spread or laid over the surface of the soil as a covering to retain moisture in the soil, maintain soil temperature, suppress weeds, and soil productivity is called mulch (Kumar & Lal, 2012). Mulch is probably derived from the German word “molsch” means soft to decay, which apparently referred to the use of straw and leaves by gardeners as a spread over the ground as mulch (Jacks, Brind, & Smith, 1955). Rowe-Dutton (1958) defined mulching as an application of layer of covering material on the soil surface. Mulching increases the growth and yield of crops, improves nutrient utilization, soil moisture status, weed suppression, temperature regulation of upper layers and disease control of soil (Solaiappan, Krishnadoss, & Senthivel, 1999).

The use of mulch films can be viewed as a positive step toward a more sustainable model of large-scale agriculture in a number of ways. First, soil erosion is greatly limited by the use of these films, as rain cannot fall directly onto soil, and wind cannot carry it away (Scarascia-Mugnozza, Schettini, & Vox, 2004). Second, the use of mulch films dramatically reduces the requirement for irrigation because evapotranspiration is reduced (Ramalan & Nwokeocha, 2000). Third, through the addition of pigments such as carbon black to otherwise transparent or translucent polymers, mulch films can partially or completely block sunlight and thus prevent any plants from growing that are not planted in holes punched or cut in the films (Snyder, Grant, Murray, & Wolff, 2015). In this way, the use of agricultural mulch film reduces competition for soil nutrients without the use of herbicides (Greer & Dole, 2003).

The dark colors, blue, and red, resulted in higher soil temperatures than white or silver colored mulches. Soil temperatures and warmer air did not always correlate to higher yield. Early yield was generally greatest with dark colored mulch and the combined total yield greatest with blue and black plastic mulch (Gordon, Foshee, Reed, Brown, & Vinson, 2010). Plastic mulch did increase yield over bare soil.

2.7.1 Effect of mulching in temperature

Plastic mulches have been used commercially on vegetables since the early 1960s (Lamont, 2005). Much of the early research before 1960 was conducted on the impact of color (black and clear) plastic mulching on soil and air temperature, moisture retention, and vegetable yields (Emmert, 1957).

The color of the plastic mulch determines its behavior of thermal properties (reflectivity, absorptivity, or transmittance) and its influence on the microclimate around the vegetable plant (Lament, 1993). Color determines the surface temperature of the mulch and underlying soil temperatures. Black plastic mulch is an opaque black body absorber and radiator that absorbs the most of the visible and infrared wavelengths of incoming solar radiation and re-radiates absorbed energy in the form of thermal radiation or long wavelength infrared radiation. Due to the radiation and forced convection, much of the solar energy absorbed by black plastic mulch is lost to the atmosphere. The efficiency of black plastic mulch in increasing the underlying soil temperature can be increased by optimizing the conditions for transferring heat from the mulch to the soil. Thermal conductivity of soil is higher to that of air. Therefore, a large portion of energy absorbed by black plastic mulch can be transferred to the soil by conduction if there is good contact between the plastic mulch and the soil surface (Lamont, 2005). Soil temperatures, under black plastic mulch, during the day time are generally 2.8^{0}C (5^{0}F) higher at a 5 cm depth and 1.7^{0}C (3^{0}F) higher at a 10 cm depth compared to bare soil (Lamont, 2005; Snyder et al., 2015).

In contrast, transparent plastic mulch absorbs little solar radiation but transmits 85% to 95% depending on the thickness and degree of opacity of the polythene. The lower surface of the plastic mulch is covered with condensed water droplets which allows to incoming short-wave radiation but restrict the outgoing longwave infrared radiation due to which much of the heat lost to the atmosphere from a bare soil by radiation is retained by the clear mulch (Streck, Schneider, Buriol, & Heldwein, 1995). Therefore, daytime soil temperature under transparent plastic mulch are generally 4.4-7.8^{0}C (8-14^{0}F) higher at 5 cm depth and 3.3-5^{0}C higher at 10 cm depth compared to bare soil. However, the difference of the temperature of bare soil and soil beneath the plastic mulch is not linear. When the bare soil temperature increases, the difference between bare soil and that measured beneath the plastic mulch decreases, such that at the lowest ambient temperatures the warming effect on under the plastic mulch is greatest (i.e., the increase in temperature is greatest) and when ambient temperatures are higher, the temperature of root zone under the plastic mulch shows the plastic mulch warm the least or may even cool the underlying soil (Laulina & Hasan, 2018; Snyder et al., 2015).

White, white on black, or silver reflective mulches may result in a slight decrease in soil temperature 1.1^{0}C (2^{0}F) at 2.5 cm depth or 0.4^{0}C (0.7^{0}F) at 10 cm depth compared to bare soil because they reflect back into the plant canopy most of the incoming solar radiation. Therefore, these mulches are used to established crops like tomatoes or cauliflower in mid-summer, when soil temperatures are high and any reduction in soil temperatures is beneficial (Lamont, 2005; Snyder et al., 2015).

2.7.2 Effect of mulching on light intensity

Light intensity in screen house or PEN house is low compared to open field (Tanny, 2013). Silver plastic mulches have the effect of changing the amount and quality of light reflected up into the plant canopy resulting high light intensity for plant (Ham, Kluitenberg, & Lamont, 1993; Hutton & Handley, 2007).

2.7.3 Effect of mulching on soil moisture

Due to the high degree of impermeability of plastic mulches to water vapor, soil water evaporative loss is minimized. The use of drip irrigation in co-occurrence with plastic mulch reduces soil moisture evaporation from the mulched soil and decreases irrigation requirements (Lamont & William, 2017). This has been related to water savings of 45% compared to overhead sprinkler systems (Clough, Locascio, & Olson, 1987).

2.7.4 Effect of mulching on weed population

Mulches contribute to weed management in organic crops by reducing weed seed germination, blocking weed growth, and favoring the crop by conserving soil moisture and sometimes by moderating soil temperature. Opaque synthetic mulches like black plastic provide an effective barrier to most weeds and are amenable to mechanized application, but they must be removed at the end of the season. Organic mulches like straw suppress annual weed seedlings, conserve moisture, and add organic matter as they break down, but they are more labor-intensive to apply.

Black, reflective, white-on black, and wavelength-selective mulches will reduce light penetration into the soil (Lamont & William, 2017). Weeds generally cannot survive under the mulch. An exception is nutgrass, whose nut-like tubers provide enough energy for the seedling to puncture the mulch and emerge. With clear plastic mulch, a herbicide or fumigation is needed to prevent weed growth beneath it.

2.7.5 Effect of mulching on fertilizer leaching

The exposed soil is exceptionally susceptible to the destructive effects of heavy rainfall, which causes the soil structure to break apart and intensifies the elimination of nutrients. This is evidenced by the results obtained by Siwek, Kalisz, and Domagala-Swiatkiewicz (2015), where the lowest nitrogen level (especially in the nitrate form) was recorded on the unprotected control site. Excess water runs off the impervious mulch. Fertilizer beneath the mulch is not lost by leaching (Lamont & William, 2017). The plastic mulch aids in retention of nutrients within the root zone, permitting more efficient nutrient use by the vegetable crop (Wang & Xing, 2016).

2.7.6 Effect of mulching on soil compaction

Mulches protect soils from wind water, traffic induced erosion and compaction that directly contribute to root stress and poor plant health (Chalker-Scott, 2007). Even adding a thin organic mulch will protect soils. For instance using a straw mulch can reduce erosion and overland flow. Using organic mulch on compact soils restores soil aggregation and porosity. It is better to apply mulch before compaction occurs as it is difficult to reverse. Proactive mulching will protect soil integrity.

2.7.7 Effect of mulching on product quality

The edible product from a mulched crop is clean and less subject to rots, because soil is not splashed on the plants or fruit. This is accomplished by a raised bed that is firm and tapered away from the row center, and plastic mulch that is stretched tightly to encourage water runoff (Lament, 1993).

2.7.8 Effect of mulching on fumigation and soil solarization

Mulches increase the effectiveness of soil fumigant chemicals. Because of the impervious nature of the plastic mulch, it acts as a barrier to gas escape and keeps gaseous fumigants in the soil (Stapleton, 1996). Plastic mulches, especially clear, are used in soil solarization to control soil pests.

2.8 Climate change impact on okra cultivation

Climate change is widely experienced in Nepal. The temperature is rising at an average of 0.4°Celsius per decade hence affecting soil moisture. Due to increased evapotranspiration; rainy days are decreasing at a rate of 0.8 days per year (Regmi & Adhikari, 2007) that decrease the vegetable production and productivity specially dry season vegetables like okra. A significant change in climate on a global scale will affect agriculture and consequently may have impact on the world's food supply. Climate change itself is not necessarily harmful; the problems arise from extreme events that are difficult to predict (Oli, 2015). More erratic rainfall patterns and unpredictable high temperature spells will consequently reduce the crop productivity. Developing countries in the tropical areas will be particularly vulnerable. Latitudinal and altitudinal shifts in agro-economic zones and ecological zones, land degradation, extreme geophysical events;, reduced water availability, and rise in sea level and salinization are postulated (Oli, 2015). Unless measures are undertaken to mitigate the effects of climate change, food security in developing countries in the tropical areas will be under threat.

Okra seeds have thick seed coats and contain lipids. These factors can slow seed hydration. Okra seeds upon hydration improve seed emergence in the field. Marsh (1993) showed that increased moisture content promotes seed germination.

2.9 Pest exclusion net

Depending on the type of crop climatic region, screen and structure configuration recent studies have shown that compared to open field conditions, reduce net air velocity and solar radiation by about 50–87% and 15–39% respectively; decrease air temperature and evapotranspiration by 2.3–2.5 °C and 17.4–50% respectively; increase air relative humidity by 2–21% (Mahmood, Hu, Tanny, & Asante, 2018).

Depending on the net material and its properties, net houses are used to achieve various objectives, such as: exclusion of virus transmitting insects and birds (Möller, Cohen, Pirkner, Israeli, & Tanny, 2010) and consequently reduced pesticide requirements; sensitive spectral absorption of light for pest control (Antignus, Lapidot, Hadar, Messika, & Cohen, 1998); reducing the vulnerability of hail and wind damage (Ilić, Milenković, Šunić, Fallik, & Agriculture, 2015; Möller et al., 2010; Stamps, 2009); extension of the growing period and delay of fruit ripening; reduction of radiative heat loss and cooling at night (Möller et al., 2010); and shading from supra-optimal radiation (Möller et al., 2010; Raveh et al., 2003).

Plant height inside pest exclusion net is found higher as compared to outside (Rahman, 2019). Fruit yield was also lower inside PEN as compared to outside. Similarly, insect infestation was also found lower inside PEN. Rahman (2019) in his study on cabbage found that individual weight of cabbage was lower in PEN compared to no PEN condition. The light interception in netting condition is lower than that of the open condition. Thus, photosynthetically active radiation (PAR) is lower in PEN. Möller et al. (2010) reported that screen transmission reduced linearly with time by about 0.1% per day during the rainless summer due to dust accumulation on the screen, but recovered after rain. The initial transmissivity was about 90% and it was reduced to about 75% by the end of the summer. Accumulation of dust on the screen is another problem that might be the reason for further reduction of PAR in PEN (Mahmood et al., 2018). Incidence of insect pest and disease inside PEN compared to outside condition was lower (Gogo, Saidi, Itulya, Martin, & Ngouajio, 2012).

2.10 Plant protection

Twenty five percent of leaf damage can tolerate by okra before significant yield loss (Oli, 2015). Major insect pest of okra are jassid (*Amrasca biguttula biguttula* Ishida), tobacco caterpillar (*Spodoptera litura* Fab), spotted bollworm (*Earias vittela* Fab.), cotton leaf roller (*Syllepta derogata* Feb.), cotton semilooper (*Anomis flava* Fab.) and the red cotton bug (*Dysdercus coenigii* Fab.) (Neupane, 1989). Jassid is most serious insect pest and may cause complete destruction of plant (Thapa, Neupane, & Adhikari, 1994).

The crop is prone to damage by various diseases caused by various insects, fungi, nematodes and viruses. But its cultivation is seriously threatened by attack of one most important Yellow Vein Mosaic Virus (YVMV), a major cause of crop failure in Asia, by affecting different parts of plant which causes heavy losses not only in respect to the fruit yield but fruit quality and occurred at all crop growth stages. YVMV transmitted by whitefly (*Bemisia tabaci* Gen.) (Kumar, Verma, Kumar, Sinha, & Kumar, 2017). These viruses can only be controlled through control of the vectors.

The most serious fungal diseases of okra plant are damping-off (*Rhizoctonia solani* and *Pythium aphanidermatum*), Vascular wilt (*Fusarium oxysporum*), Cercospora blight (*Cercospora abelmoschus*, *Cercospora malayensis*) and powdery mildew (*Erysiphe cichoracearum*, *Oidium abelmoschi*)(Kumar, Kumar, & Nadendla, 2013).

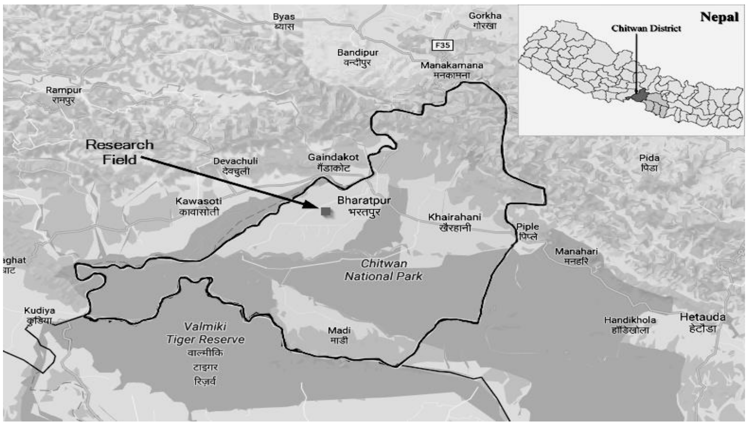
Root-knot nematode (*Meloidogyne* sps) is also one of the major pest attacking okra, particularly in areas having lighter soil. Affected plants exhibits stunting, yellowing and wilting, and subsequently dying due to food starvation (Mondal, Chakraborty, Roy, & Karmakar, 2016).

3 MATERIALS AND METHODS

This chapter includes all the materials and methodologies used during the research entitled “Effect of Pest Exclusion Net and Mulching on Okra Production at Rampur, Chitwan, Nepal”. The methods and methodologies are well described below:

3.1 Experimental site

The study was conducted at Horticulture Research Farm of Agriculture and Forestry University (AFU), Rampur, Chitwan, Nepal in summer season (from May, 2018 to August, 2018). Chitwan district lies in inner Terai region. This district is popular for agricultural production including the seasonal and off season vegetable production. The district is situated in the middle part of Nepal which covers 2,118 km^2 in area.



Geographically, the field lies at latitude 27º 37' N and longitude 84º 25' E with an altitude of about 228 m above sea level. The research site is almost plain land with sandy loam type of soil. Meteorological data were collected and recorded on 15 days interval. Soil temperature was recorded using soil thermometer. Atmospheric temperature and relative humidity were obtained using thermo hygrometer and the light intensity was recorded using luxmeter.

3.2 Climate

Chitwan is located in the central climatic zone of the Himalayas, where monsoon starts in mid June and stops in late September. Approximately 80% of the total annual precipitation occurs during this period. After mid-October the monsoon clouds have retreated, humidity drops off, and the top daily temperature gradually subsides from 36°C to 18°C. Nights are cooling down to 5°C until late December, when it usually rains softly for a few days. Then temperatures are rising gradually.

3.3 Experimental design

The field was first prepared by ploughing and removal of weeds. It was leveled and then experiment was laid out in Randomized Complete Block Design (RCBD). The study had five treatments and four replications. There were 20 plots in main field. Each plot was of the 3m×2.8m (8.4m^2). The total area of the main field was 273.6m^2. The spacing between the plots was 0.5m and the spacing between two replications was 1m.

The treatments included in this study are as given below:

T1: Control (No net + no mulch)

T2: Rice straw mulch

T3: Black plastic mulch

T4: Silver colored plastic mulch

T5: Pest exclusion net + black plastic mulch

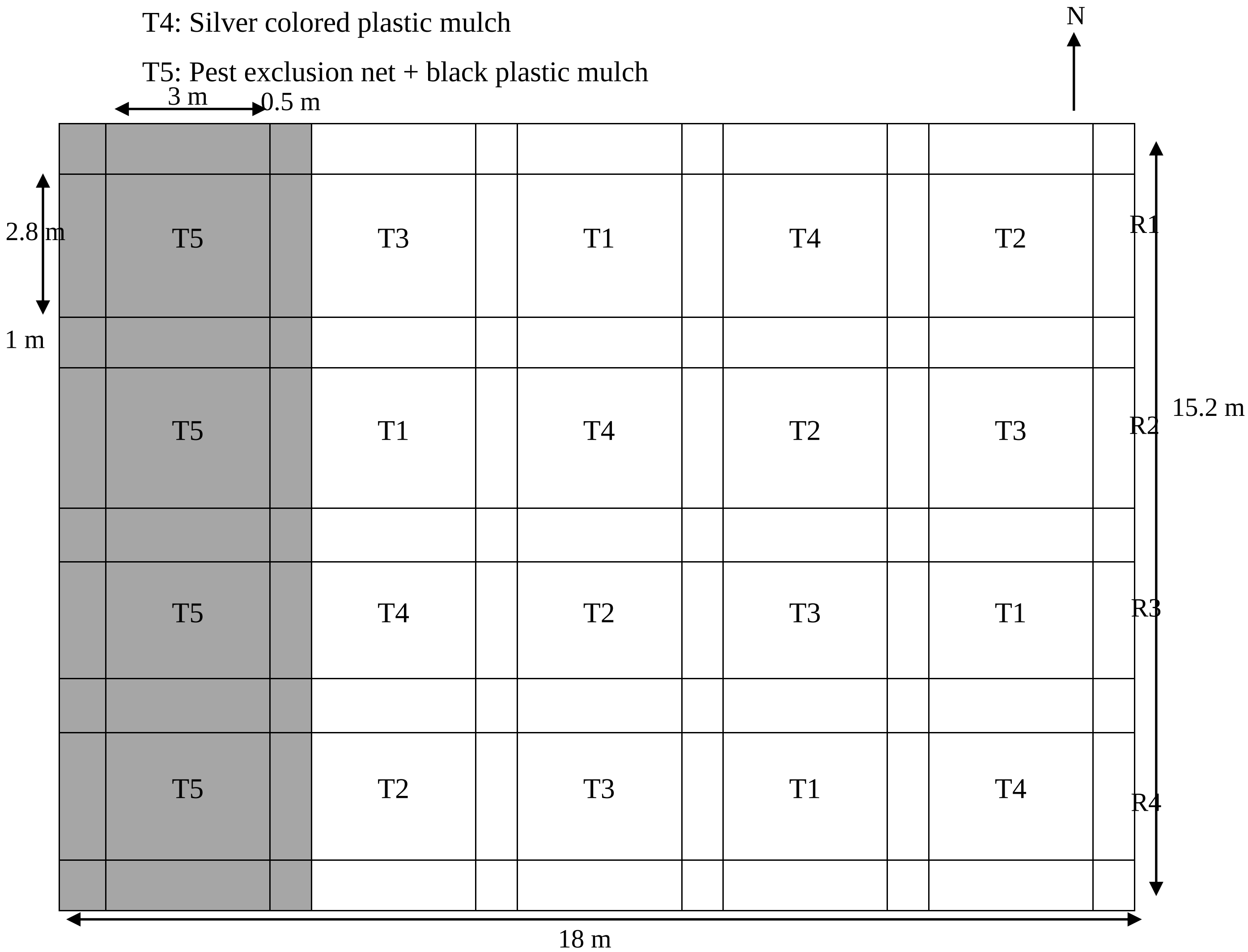


Figure 2. Layout of research site

Research details:

Table 2. Research details on okra at Rampur, Chitwan, Nepal.

Location	Horticulture Research Farm, AFU, Rampur, Chitwan
Design	Randomized Complete Block Design
Name of crop	Okra
Variety	Swastik 2 F1
Spacing	Row to row-60cm
	Plant to plant-40cm
Total area of field	273.6 m^2
Total area of individual plot	8.4m^2
Number of treatments	5
Number of replication	4
Total number of plots	20
Seed sowing date	2075/01/25 B.S. (2018/05/08 A.D.)
Harvesting date	2075/03/05 (2018/ 06/19 A.D.) onwards at an interval of 3 days upto 14 harvest.

The description of the materials used in different treatments is as below:

Black plastic mulch

Black plastic mulch used in the research was of 25 micron. One roll contained 200 m of black plastic mulch. It was used because of its property to increase soil temperature in cold condition.

Silver plastic mulch

Plastic of 25 micron which was silver colored at one side and black on other side was used.

Straw mulch (Rice straw mulch)

Properly dried rice straw was obtained from agronomy farm. It was spread at the thickness of about 10 cm at the time of application. The treatment was chosen due to the properties of organic mulch to avoid fluctuating soil temperature.

Net properties

The pest exclusion net used for the research was of the dimension 16m × 6m. The central height of PEN was 5m while the side height was 3m. It was an alumino net. It was of mesh size 40. It had a single entrance of chain system. The shading percentage of the roof was 50%.

Description of seed and variety used in research

Swastik 2 F1 hybrid variety was selected. It can be cultivated in terai and hilly region. The potential yield of this variety is 20-25 t ha-1. It has short maturity period of 45 days. So, the variety was preferred. The seed of Swastik 2 F1 hybrid of okra was taken from Sudhar Agrovet, Chitwan. The purity of seed was 99%.

3.4 Meteorological data of research site

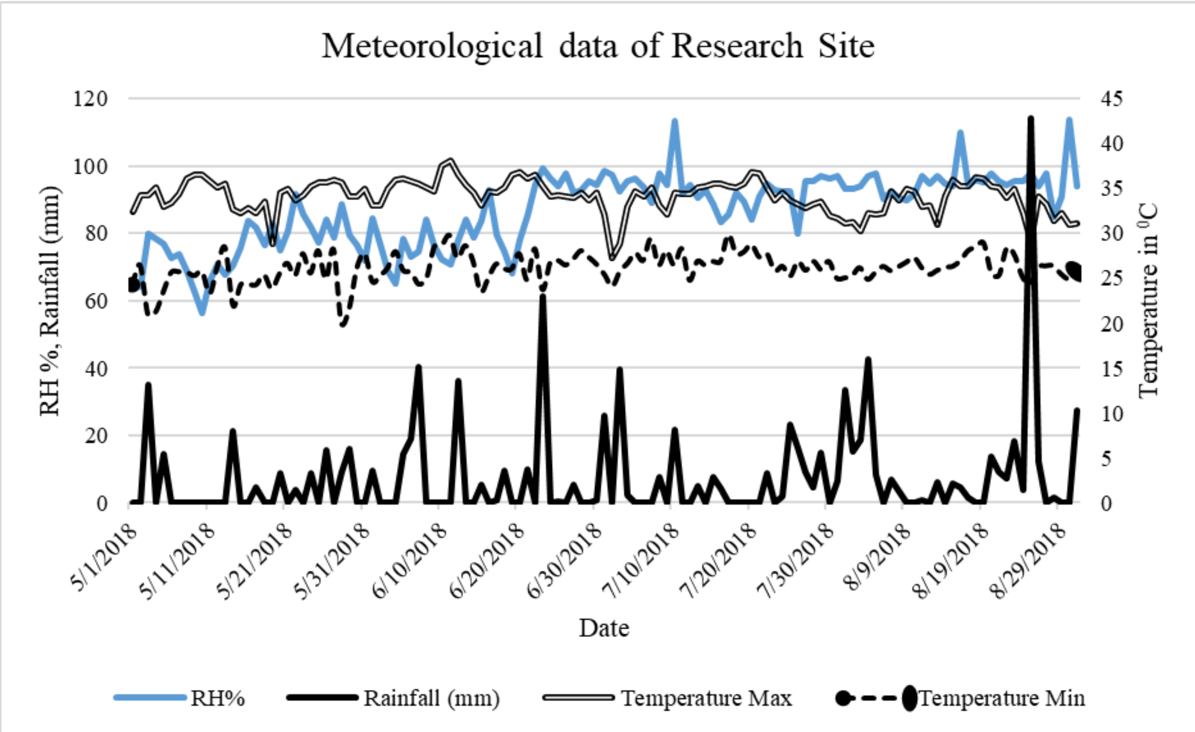


Figure 3. Meteorological data of research site at Rampur, Chitwan, Nepal, 2018

3.5 Cropping history

The field was mainly used for the research on vegetable crop. In earlier year, the field was used for the research in Cauliflower.

3.6 Agronomic operations

3.6.1 Field preparation

The main experimental field was thoroughly ploughed and harrowed two times. Field was leveled using raker and weed was also removed. Net house was also ploughed manually two times and all the weeds were removed. Plot was raised using spade. Ploughing was done on the last week of April. After field preparation, field was laid out in Randomized Complete Block Design (RCBD) with five treatments and four replications. There were 20 plots with total area of 273.6 m^2. Individual plot was of the size 3m×2.8m (8.4m^2).

3.6.2 Formalin treatment

Soil was treated with formalin 5 days prior to planting. Firstly, the formalin was diluted with water in the ratio of 1:49 and then it was sprayed all over the field and the field was immediately covered with black plastic after spraying for not letting the formalin to evaporate. It was kept as it for about 48 hours and then plastic was removed and the field was left uncovered for 24 hours.

3.6.3 Manure and fertilizer application

FYM @ 25 kg per plot was applied 15 days prior to seed sowing so that it get properly mixed in soil for the proper growth and maintenance of plant. It was broadcasted in the individual plot and ploughed once. Full dose of DAP (91.31g/ plot), MOP (56g/ plot) and 30% urea (28.2g/ plot) were applied as basal dose on the day of planting while the remaining dose of urea (63.9g/ plot) was applied one month after sowing.

- Urea containing 46% Nitrogen
- DAP containing 46% Phosphorus and 18% Nitrogen
- MOP containing 60% Potassium
- Recommended dose of FYM was 30t ha-1
- Recommended dose of NPK was 70:50:40 kg NPK ha-1

3.6.3 Seed sowing

The seeds were sown on 8th May, 2018. In the mulch designated plots, black polyethylene mulch, silver plastic mulch and organic mulch was placed on the day of sowing. Holes were made on the plastic mulch. Then 1 seed was placed in each spot. Each plot had 5 rows of 7 plants.

3.6.4 Gap filling

Gap filling was done after one week of seed sowing. The dead or damaged seedlings were taken out and fresh new seed were sown in its place.

3.6.5 Irrigation and weeding

Irrigation was done as per the requirements by the plants and also as per the prevailing weather condition. Weeding was done on regular interval on all the plots.

3.6.6 Observation and monitoring

Ten plants per plot were randomly selected and tagged. Data of plant parameters and insects damage were taken from the tagged plants. Following parameters were taken.

3.6.6.1 Growth parameter

• **Days to germination**

Days required to germinate 50% seed is taken as days to germination.

• **Plant height**

Plant height of randomly selected 10 sample plants was measured from the ground level to the growing tip with the help of graduated scale at every 15 days interval starting from 20 days after sowing till 80 days after sowing.

• **Leaf number per plant**

Leaf number was measured at 80 days after sowing from randomly selected 10 plants and average was calculated.

• **Stem diameter**

Stem diameter was measured from the 10 randomly selected plants at 80 days after sowing using vernier caliper.

• **Days to 50% flowering**

The days to 50% flowering from the sample plants were recorded from the date of sowing.

• **Fruit length**

Fruit length was recorded from the sampled plant. Five different fruit were taken to measure length with the help of graduated scale.

• **Fruit diameter**

The diameter of the fruit was recorded from the fruits of sample plants. Recording were taken from basal, mid-point and tip with the help of Vernier caliper and the value were averaged.

• **Fresh fruit weight**

With the help of electronic balance, fresh weights from sampled plants were taken and divided with fruit number of those number of fruit from sampled plant.

• **Branch number**

Branch number was recorded from the 10 randomly selected plants at 80 days after sowing.

• **Yield**

Okra yield was converted in metric ton per ha from the total weight of harvested fruit at an interval of 3 days after first harvesting.

3.6.6.2 Physical parameter

Meteorological data were collected and recorded on a 7 days interval.

- **Soil temperature**

Soil temperature was recorded with the help of soil thermometer from the soil depth of the 10cm.

- **Soil moisture content**

Soil moisture content (% vol) was recorded using HH2 Wet sensor Moisture Meter of Delta-T Devices Ltd. Soil moisture was recorded at depth of 10 cm from 5 different places randomly in interval of 7 days. Moisture content reading was taken in volumetric methods by device itself.

- **Atmospheric temperature and humidity**

Atmospheric temperature and humidity were measured at weekly interval using thermo hygrometer inside and outside of the PEN house.

- **Light intensity**

Luxmeter was used to record the intensity of light inside and outside of PEN house.

3.6.6.3 Physiological parameter

- **Physiological loss in weight**

Ten fruits in each treatment per replication were stored in ambient condition. Initial weight of 10 fruits was recorded with **electronic digital balance**. Weights of okra fruits were taken at each 3 days interval at storage. Physiological loss in weight (percentage) was determined by using following formula:

Plhysilogical Loss in Weight (%) =

$$\left(\frac{initial\ weight - final\ weight}{initial\ weight}\right) \times 100$$

The cumulative physiological loss in weight (PLW) of the okra was recorded at every 2 days interval.

3.6.6.4 Weed parameter

Weeding was done at 30 days after sowing, 45 days after sowing and 60 days after sowing. The fresh weight of weed per plot were recorded using electronic balance and data were recorded.

3.6.6.5 Entomological parameter

- **Monitoring of aphid, jassids and whiteflies:**

Aphid, jassids and whiteflies recording were counted on sample plants. Number of pest (aphid, jassids and whitefiles)/sample plant (10 plants from each plot) were recorded at 20 days after sowing at a week interval. Monitoring of aphid, jassids and whiteflies were done usingYellow Sticky Trap. The trapped aphids, jassids and whiteflies were counted from each trap on weekly interval.

4 RESULTS

4.1 Effect of pest exclusion net and mulching on growth parameter of okra plant

4.1.1 Plant height

The height of okra plant under different treatment at 15 days interval after 20 days of seed sowing is presented in Table 3.

Table 3. Effect of pest exclusion net and mulching on height of okra plant at Rampur, Chitwan, Nepal, 2018

Treatments	Plant height (cm)				
	20 DAS	**35 DAS**	**50 DAS**	**65 DAS**	**80 DAS**
Control	12.69^{c}	47.11^{b}	104.04^{c}	152.68^{c}	155.58^{c}
Straw Mulch	16.32^{b}	52.58^{b}	123.1^{b}	164.2^{bc}	167.2^{bc}
Black Plastic Mulch	15.67^{bc}	50.1^{b}	119.81^{b}	174.25^{b}	177.63^{b}
Silver Plastic Mulch	15.26^{bc}	51.81^{b}	116.73^{b}	179.15^{b}	182.48^{b}
PEN+Black Plastic Mulch	22.35^{a}	66.93^{a}	160.4^{a}	209^{a}	212.93^{a}
SEM (±)	1.597	3.43	9.46	9.44	9.62
CV (%)	11.99	9.34	5.51	6.98	6.99
LSD (0.05)	3.042	7.72	10.60	18.93	19.23
F-test	**	***	***	***	***

Treatment means in same columns followed by common letters are not significantly different from each other based on LSD at 5% level of Significance. * , ** and *** indicates significant at 0.05, 0.01 and 0.001 respectively. DAS= days after sowing, PEN= pest exclusion net, SEM(±)= standard error of mean, CV%= coefficient of variance, LSD= least significance difference.

Analysis of variance (ANOVA) revealed that there was significant difference among the different treatments regarding the plant height at different days after seed sowing. In all the days after sowing, the highest plant height was obtained in case of pest exclusion net and black plastic mulch and the lowest in case of control. At 20 days after sowing, the height was significantly higher with the combination of pest exclusion net and black plastic mulch i.e. 22.35 cm. The plant height with straw mulching, black plastic mulching and silver plastic mulching were at par whereas plant height with control treatment was recorded as the lowest (12.69 cm).

At 35 days after sowing, the height of okra plant in pest exclusion net + black plastic mulching (66.93 cm) was the highest. Plant height of okra in silver plastic mulching, black plastic mulching, straw mulching and control treatments were not significantly different.

At 50 days after sowing, the plant height in pest exclusion net with black plastic mulch was 160.4 cm. Okra plant with straw plastic mulching, black plastic mulching and silver plastic mulching revealed the significantly same plant height whereas plant height with control treatment was significantly dwarf (104.4 cm).

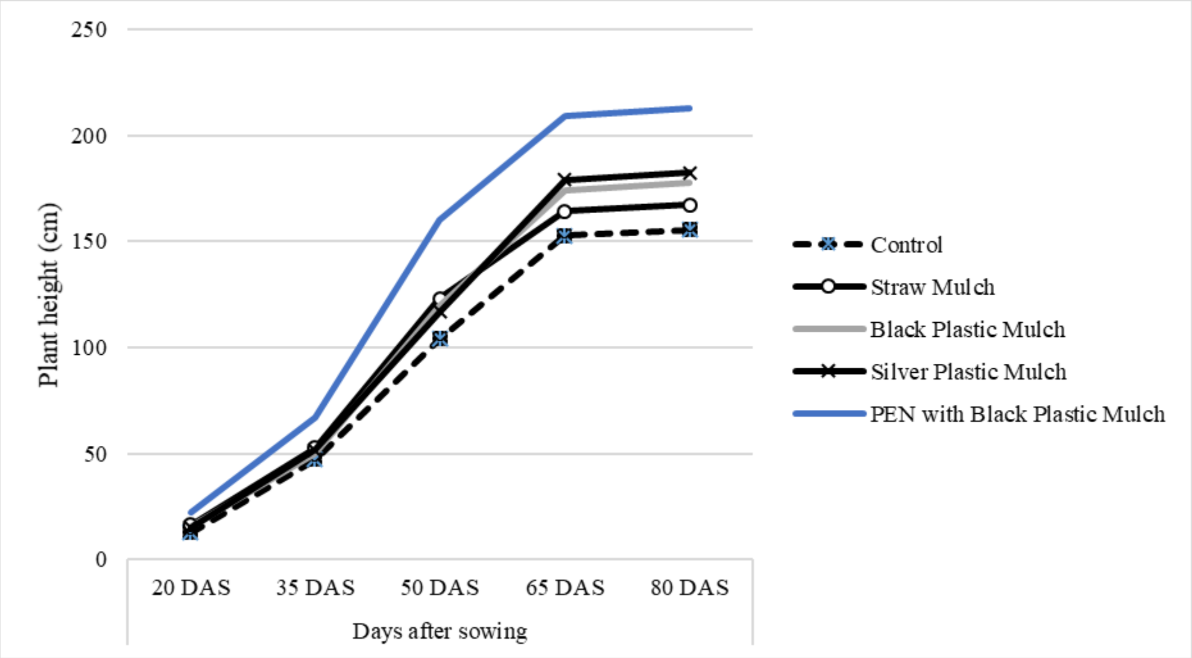


Figure 4. Effect of pest exclusion net and mulching on plant height of okra at Rampur, Chitwan, Nepal, 2018

After 80 days of seed sowing, significantly higher plant height of 212.93 cm was obtained in pest exclusion net combined with black plastic mulch, which was followed by plant height of silver plastic mulching (182.48 cm), black plastic mulching (177.63 cm), straw mulching (167.2 cm) and control (155.58 cm) .

4.1.2 Stem diameter, leaf number and days to flowering

Stem diameter and leaf number were recorded at 80 days after sowing. ANOVA revealed significant difference regarding stem diameter, leaf number and days to 50% flowering (Table 4). Stem diameter of the plant with silver plastic mulching (25.73 mm) was found as the highest which was at par with the PEN+black plastic mulching (25.41 mm), black plastic mulching (24.96 mm) and straw mulching (23.01 mm). The lowest stem diameter of plant was obtained with control (20.51 mm). Similar condition was obtained in case of leaf number. The highest leaf number was obtained for silver plastic mulch (27.98) which was followed by black plastic mulch (26.73), straw mulch (22.65), control (19.25) and PEN+black plastic mulch (15.58).

Table 4. Effect of pest exclusion net and mulching on stem diameter, leaf number and days to 50% flowering of okra at Rampur, Chitwan, Nepal, 2018

Treatments	**Parameters**		
	STD (mm)	**LFN**	**DTF**
Control	20.51^{b}	19.25^{c}	42^{ab}
Straw Mulch	23.01^{ab}	22.65^{b}	41^{bc}
Black Plastic Mulch	24.96^{a}	26.73^{a}	39.75^{cd}
Silver Plastic Mulch	25.73^{a}	27.98^{a}	38.5^{d}
PEN+black Plastic Mulch	25.41^{a}	15.58^{d}	43^{a}
SEM (±)	2.18	2.30	0.80
CV %	7.90	4.4	2.57
LSD (0.05)	2.91	1.52	1.61
F-test	*	***	***

Treatment means in same columns followed by common letters are not significantly different from each other based on LSD at 5% level of Significance. * , ** and *** indicates significant at 0.05, 0.01 and 0.001 respectively. STD= stem diameter, LFN= leaf number per plant, DTF= days to 50% flowering, PEN= pest exclusion net, SEM(±)= standard error of mean, CV%= coefficient of variance, LSD= least significance difference.

Comparatively early flowering was obtained in okra planted with the silver plastic mulch (38.5 days after sowing) which was as at par with black plastic mulch (39.75cm). The late flowering was obtained in plant with PEN+black plastic mulching (43 days after sowing).

4.1.3 Fruit length, fruit diameter and fruit weight

Means of fruit length, fruit diameter and fruit weight were found significantly different (Table 5). Fruit length, fruit diameter and fruit weight were recorded as the highest with PEN+black pastic mulch. Mean length of fruit in PEN+black plastic mulch was 18.26 cm which was followed by silver plastic mulch (17.28 cm), black plastic mulch (16.46 cm), straw mulch (16.30 cm) and control (16.01 cm). Fruit diameter of okra with PEN+ black plastic mulching was the highest (17.34 mm) followed by silver plastic mulching (16.66 mm), black plastic mulching (16.53 mm), straw mulching (15.77 mm) and control (15.30 mm).

Table 5. Effect of pest exclusion net and mulching on fruit length, fruit diameter and fruit weight of okra at Rampur, Chitwan, Nepal, 2018

Treatments	**Parameters**		
	FRTL (cm)	**FRTD (mm)**	**FWT (gm)**
Control	16.01[c]	15.30[c]	22.34[b]
Straw Mulch	16.30[c]	15.77[c]	24.24[b]
Black Plastic Mulch	16.46[bc]	16.53[b]	23.91[b]
Silver Plastic Mulch	17.28[b]	16.66[b]	23.46[b]
PEN+black Plastic Mulch	18.26[a]	17.34[a]	32.80[a]
SEM (±)	0.41	0.36	1.90
CV %	3.43	2.38	10.81
LSD (0.05)	0.89	0.60	4.22
F-test	***	***	**

Treatment means in same columns followed by common letters are not significantly different from each other based on LSD at 5% level of Significance. * , ** and *** indicates significant at 0.05, 0.01 and 0.001 respectively. FRTL= pod/fruit length in cm, FRTD= pod/fruit diameter in mm, FWT= pod/fruit weight in gm, SEM(±)= standard error of mean, CV%= coefficient of variance, LSD= least significance difference.

Fruit weight of plant with PEN+black plastic mulch was the highest (32.8 gm) which was significantly different with other treatments. Fruit weight of plant with straw mulch (24.24 gm), black plastic mulch (23.91 gm), silver plastic mulch (23.46) and control (22.34 gm) were obtained at par.

4.1.2 Branch number, Fruit number and Yield

As shown in the Table 6, the significant difference was found among the treatments in case of branch number and yield. The significantly higher branch number of plant was found with silver plastic mulch (5.1) followed by black plastic mulch (4.8), straw mulch, control and PEN+black plastic mulch (3.8). The mean branch number of plant with silver plastic mulch and black plastic mulch were at par.

From the analysis of variance, it was found that mean value of fruit number per plant was found significantly different. The highest fruit number was obtained of plant with silver plastic mulching (33.65) followed by black plastic mulching (29.77), straw mulching (24.35), control (22.37) and PEN+black plastic mulching (21.88). Fruit number of okra plant with silver plastic mulching was found at par with black plastic mulching.

Variance analysis of yield was found significant differences in values. The highest yield was obtained with silver plastic mulching (30.74 mt/ha) followed by black plastic mulching (29.39 mt/ha), straw mulching (24.40 mt/ha), control (22.71 mt/ha) and PEN+ black plastic mulching (20.40 mt/ha). Yield of plant with silver plastic mulching was found at par with plant of black plastic mulching.

Table 6. Effect of pest exclusion net and mulching on branch number and yield of okra at Rampur, Chitwan, Nepal, 2018

Treatments	**Parameters**		
	BN	**FNP**	**Yield (mt/ha)**
Control	4.15^{cd}	22.37^{b}	22.71^{c}
Straw Mulch	4.6^{bc}	24.35^{b}	24.40^{bc}
Black Plastic Mulch	4.8^{ab}	29.77^{a}	29.39^{ab}
Silver Plastic Mulch	5.1^{a}	33.65^{a}	30.74^{a}
PEN+Black Plastic Mulch	3.85^{d}	21.88^{b}	20.40^{c}
SEM (±)	0.224	2.29	1.97
CV %	6.68	13.00	13.76
LSD (0.05)	0.46	5.29	5.41
F-test	***	**	**

Treatment means in same columns followed by common letters are not significantly different from each other based on LSD at 5% level of Significance. * , ** and *** indicates significant at 0.05, 0.01 and 0.001 respectively. BN= branch number per plant, FNP= fruit number per plant, PEN= pest exclusion net, SEM(±)= standard error of mean, CV%= coefficient of variance, LSD= least significance difference.

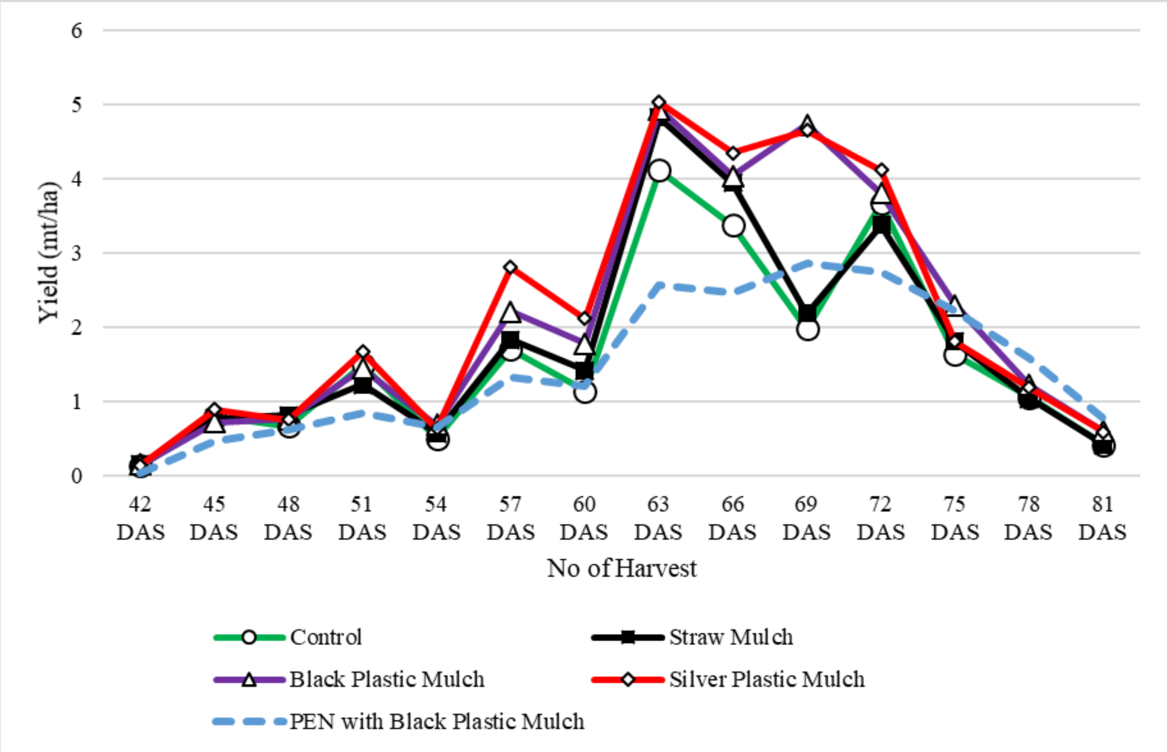


Figure 5. Effect of pest exclusion net and mulching on yield (mt/ha) of okra at Rampur, Chitwan, Nepal, 2018

The Figure 5also revealed that yield in silver plastic mulch was distinctly higher. Comparatively highest yield were obtained during 8th harvesting i.e., 63 days after sowing.

4.2 Effect of pest exclusion net and mulching on physical parameters

4.2.1 Soil temperature, Soil moisture content and light intensity

The ANOVA revealed that soil temperature, soil moisture content and light intensity of the treatments had significantly difference means (Table 7). Soil temperature in PEN+black plastic mulching was significantly the lowest (28.94^{0}C). The highest soil temperature was obtained with black plastic mulching (31.61^{0}C) followed by control (30.69^{0}C), silver plastic mulching (30.36^{0}C) and straw mulching (29.89^{0}C).

Soil moisture content in case of control, straw mulching, black plastic mulching, silver plastic mulching and PEN+black plastic mulching treated soil were found significantly different (Table 7. Effect of pest exclusion net and mulching on soil temperature, soil moisture content and light intensity (Lux) of okra growing condition at Rampur, Chitwan, Nepal, 2018Table 7). The highest soil moisture content was found in soil of PEN+ black plastic mulch (25.90%) followed by silver plastic mulching (23.99%), black plastic mulching (23.18%), straw mulching (20.68%) and control treatment (19.68%).

Table 7. Effect of pest exclusion net and mulching on soil temperature, soil moisture content and light intensity (Lux) of okra growing condition at Rampur, Chitwan, Nepal, 2018

Treatments	**Parameters**		
	Soil temperature (^{0}C)	**Soil moisture content (vol %)**	**Light intensity (Lux)**
Control	30.69^{b}	19.68^{d}	215.08^{b}
Straw Mulch	29.81^{c}	20.68^{c}	224.44^{b}
Black Plastic Mulch	31.61^{a}	23.18^{b}	224.22^{b}
Silver Plastic Mulch	30.36^{bc}	23.99^{b}	250.31^{a}
PEN+Black Plastic Mulch	28.94^{d}	25.90^{a}	110.32^{c}
SEM (±)	0.45	1.12	24.36
CV %	1.70	3.06	5.53
LSD (0.05)	0.79	1.07	17.46
F-test	***	***	***

Treatment means in same columns followed by common letters are not significantly different from each other based on LSD at 5% level of Significance. * , ** and *** indicates significant at 0.05, 0.01 and 0.001 respectively. SEM(±)= standard error of mean, CV%= coefficient of variance, LSD= least significance difference.

The mean values of light intensity (Lux) of control, straw mulch, black plastic mulch, silver plastic mulch and PEN+black plastic mulch were found significantly different (Table 7). Plant of silver plastic mulch had received highest light intensity (250.31 lux) which was followed by straw mulch (224.44 lux), black plastic mulch (224.22 lux), control (215.08 lux) and PEN+black plastic mulch (110.32 lux).

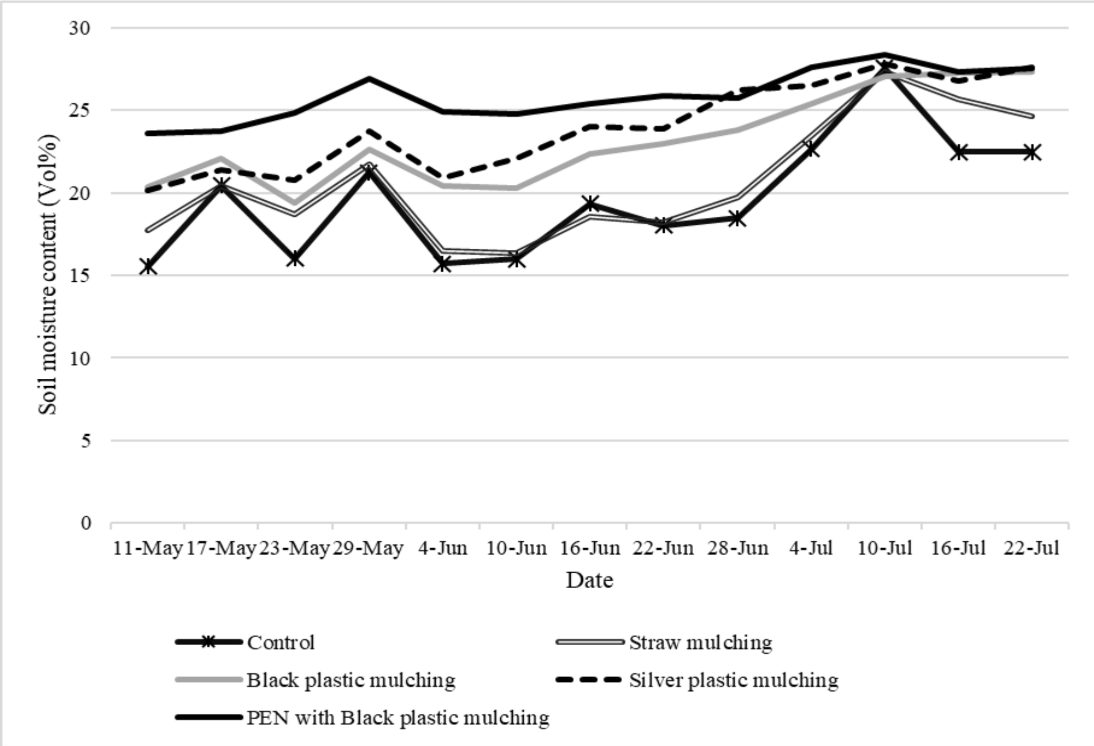


Figure 6. Effect of pest exclusion net and mulching on soil moisture content of okra field at Rampur, Chitwan, Nepal, 2018

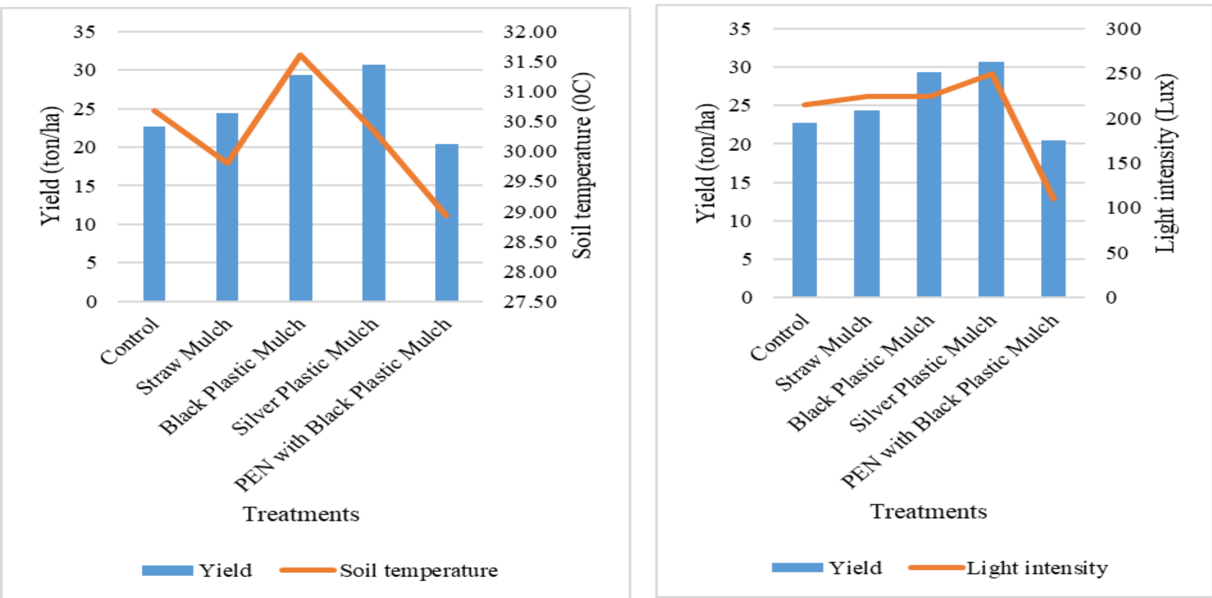


Figure 7. Effect of pest exclusion net and mulching on soil temperature and light intensity in okra field at Rampur, Chitwan, Nepal, 2018

Soil temperature and light intensity were found very low of plant with PEN+black plastic mulch while soil moisture content was found high of PEN+black plastic mulch.

4.3 Effect of pest exclusion net and mulching on germination

In this study, 50% of the seeds were germinated early in PEN+black plastic mulching (3.75 days after sowing) which was followed by silver plastic mulching (4.5 days after sowing), black plastic mulching (5 days after sowing), straw mulching (6 days after sowing) and control (6.75 days after sowing) (Table 8). Days required for 50% seed germination in PEN +black plastic mulching was at par with silver plastic mulching treated seeds. Coefficient of variation was found 15% among the treatments.

Similarly, soil temperature with each treatments were taken during the period of germination. The study revealed the highly significant differences in means (Table 8). The highest temperature was recorded in black plastic mulching (34.89^{0}C) which was followed by control treatment (34.44^{0}C), silver plastic mulching (33.82^{0}C, straw mulching (32.13^{0}C) and PEN+black plastic mulching (31.45^{0}C).

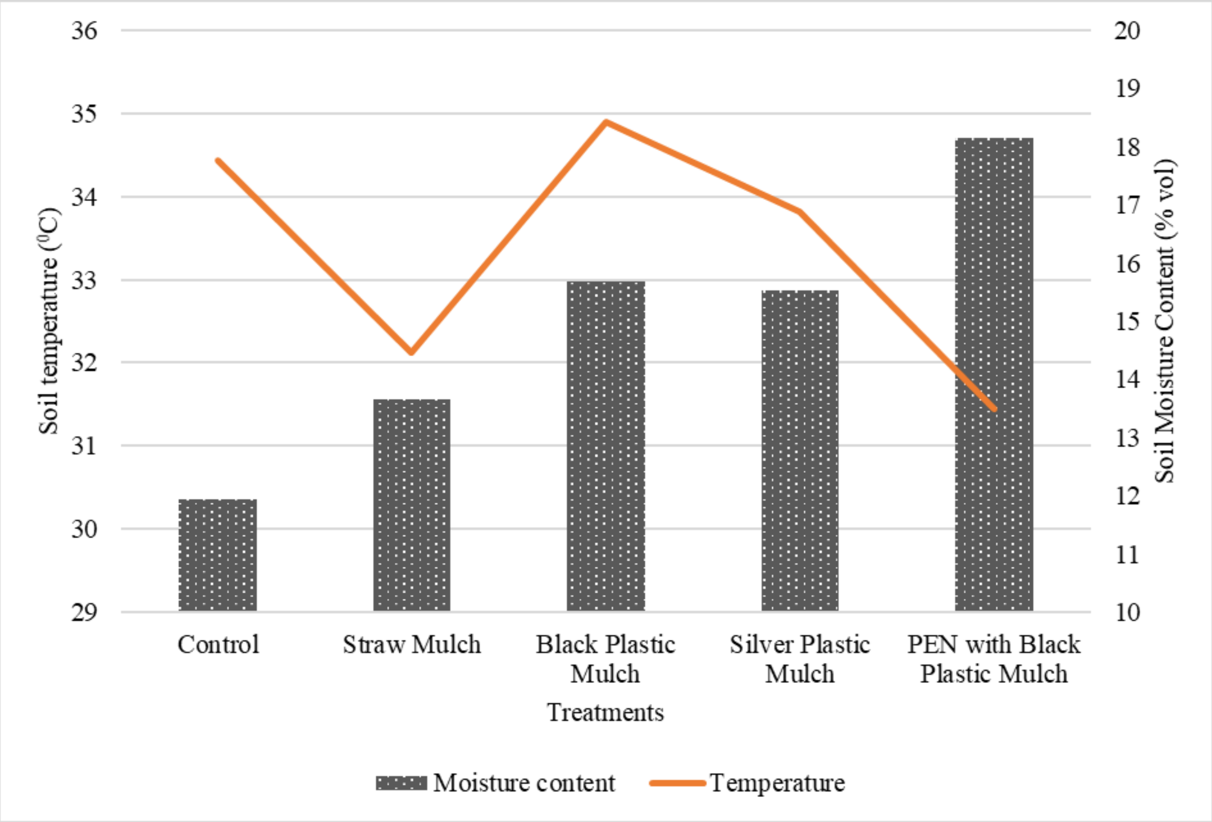


Figure 8. Effect of pest exclusion net and mulching on soil temperature and soil moisture content during germination of okra at Rampur, Chitwan, Nepal, 2018

In the study, PEN+black plastic mulch resulted in the significantly highest soil moisture content (18.15%) compared to other treatments. The lowest soil moisture content was observed with control treatment (11.95%) followed by straw mulch. Soil in case of black plastic mulch and silver plastic mulch showed moisture content value at par (Table 8).

Table 8. Effect of pest exclusion net and mulching on days to germination, temperature during germination and soil moisture during germination at Rampur, Chitwan, Nepal, 2018

Treatments	**Parameters**		
	GMD	**GMT**	**SMC**
Control	6.75[a]	34.44[b]	11.95[d]
Straw Mulch	6[ab]	32.13[d]	13.65[c]
Black Plastic Mulch	5[bc]	34.89[a]	15.68[b]
Silver Plastic Mulch	4.5[cd]	33.82[c]	15.53[b]
PEN+black Plastic Mulch	3.75[d]	31.45[e]	18.15[a]
SEM (±)	1.19	0.67	1.04
CV %	15	0.84	3.69
LSD	1.20	0.43	0.85
F-test	**	***	***

Treatment means in same columns followed by common letters are not significantly different from each other based on LSD at 5% level of Significance. * , ** and *** indicates significant at 0.05, 0.01 and 0.001 respectively. GMD= 50% germination days, GMT= germination temperature in Celsius, SMC= soil moisture content (vol%), SEM (±) = standard error of mean, CV%= coefficient of variance, LSD= least significance difference.

4.4 Effect of pest exclusion net and mulching on physiological loss in weight

The study showed that, post-harvest physiological loss in weight of okra fruit was found significantly different two days after storage and six days after storage. While non-significant difference of fruit weight was obtained for days after storage (Table). The highest weight loss of stored fruit was obtained in produce from PEN+black plastic mulch in both two days after storage (16.4%) and six days after storage (26.25%) which were found statistically at par with weight loss of black plastic mulch treated produce and silver plastic mulch treated produce. The lowest loss in weight after harvest was seen in the produce obtained from control treatment.

Table 9. Effect of pest exclusion net and mulching on physiological loss in weight of okra at Rampur, Chitwan, Nepal, 2018

Treatments	Physiological loss in weight (%)		
	2 days after Storage	4 days after storage	6 days after storage
Control	13.3[c]	18.15[a]	22.5[c]
Straw Mulch	14.95[b]	18.75[a]	24.75[b]
Black Plastic Mulch	15.5[ab]	17.85[a]	25.35[ab]
Silver Plastic Mulch	15.8[ab]	18.8[a]	25.9[ab]
PEN+black Plastic Mulch	16.4[a]	20.2[a]	26.25[a]
SEM (±)	0.53	0.41	2.40
CV %	5.49	9.35	3.88
LSD	1.29	2.7	1.5
F-test	**	NS	**

Treatment means in same columns followed by common letters are not significantly different from each other based on LSD at 5% level of Significance. * , ** and *** indicates significant at 0.05, 0.01 and 0.001 respectively. SEM(±)= standard error of mean, CV%= coefficient of variance, LSD= least significance difference.

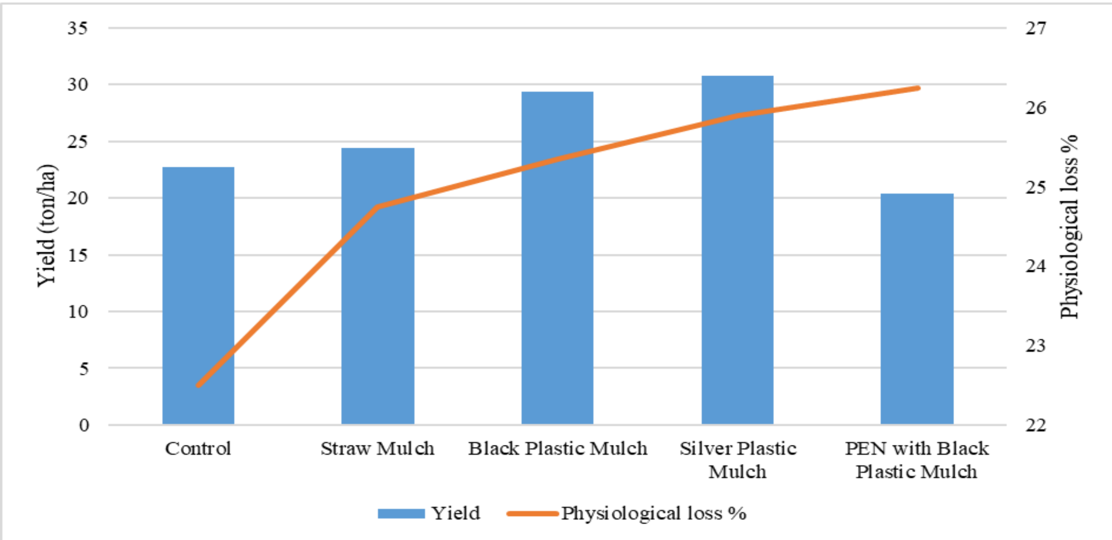


Figure 9. Yield and physiological loss in weight of okra from different treatment at Rampur, Chitwan, 2018

4.5 Effect on pest exclusion net and mulching on weed population

The ANOVA revealed that the weed infestation were found significantlydifferentin means in three weeding. The weed infestation in case of control treatment was obtained as the highest while weed infestation with PEN+black plastic mulch was obtained as the lowest. Mean fresh weight of weed in control plot after thirty days of sowing was found 5.64 kg which was followed by straw mulching (1.54 kg), silver plastic mulching (0.70 kg), black plastic mulching (0.35 kg) and PEN+black plastic mulching (0 kg). Similar result was obtained in the second weeding. The highest fresh weed weight was obtained in control treatment (7.45 kg) followed by straw mulching (2.05 kg), silver plastic mulching (0.87 kg), black plastic mulching (0.45 kg) and PEN+black plastic mulching (0.08 kg). In the third weeding (after 60 days of sowing), fresh weed weight was obtained as the highest in control treatment (3.67kg) followed by straw mulching (1.02 kg), silver plastic mulching (0.39 kg), black plastic mulching (0.20 kg) and PEN+black plastic mulching (0.11 kg). Except in control treatment, fresh weed weight were found statistically at par among all other treatments (Table0).

Table10. Effect of pest exclusion net and mulching on weeds of okra at Rampur, Chitwan, Nepal, 2018

Treatments	Weed weight (kg)		
	Fresh weight of weed 30 DAS	**Fresh weight of weed 45 DAS**	**Fresh weight of weed 60 DAS**
Control	5.64[a]	7.45[a]	3.67[a]
Straw Mulch	1.54[b]	2.05[b]	1.02[b]
Black Plastic Mulch	0.35[b]	0.45[b]	0.20[b]
Silver Plastic Mulch	0.70[b]	0.87[b]	0.39[b]
PEN+black Plastic Mulch	0[b]	0.08[b]	0.11[b]
SEM (±)	1.03	1.36	0.67
CV %	141.85	131.3	117.20
LSD	3.60	4.41	1.94
F-test	*	*	**

Treatment means in same columns followed by common letters are not significantly different from each other based on LSD at 5% level of Significance. * , ** and *** indicates significant at 0.05, 0.01 and 0.001 respectively. SEM(±)= standard error of mean, CV%= coefficient of variance, LSD= least significance difference

4.6 Effect of pest exclusion net and mulching on insect number

There were no any insect-pests recorded inside the PEN house. While outside of PEN, there were aphids, white flies, jassids and spodoptera were recorded. Aphids, white flies and jassids were monitored through yellow sticky trap while spodoptera was monitored through Spodo-Lure in funnel trap. Among the insect pest, aphids were seen in the highest number (

Table 91).

Table 91. Effect of pest exclusion net and mulching on insect population in okra at Rampur, Chitwan, Nepal, 2018

	Insect population (in number)				
Insects	**13-May**	**23-May**	**2-Jun**	**12-Jun**	**22-Jun**
Aphids	86	106	13	14	43
White flies	10	6	12	20	12
Jassids	3	12	21	23	36
Spodoptera	0	0	8	2	5

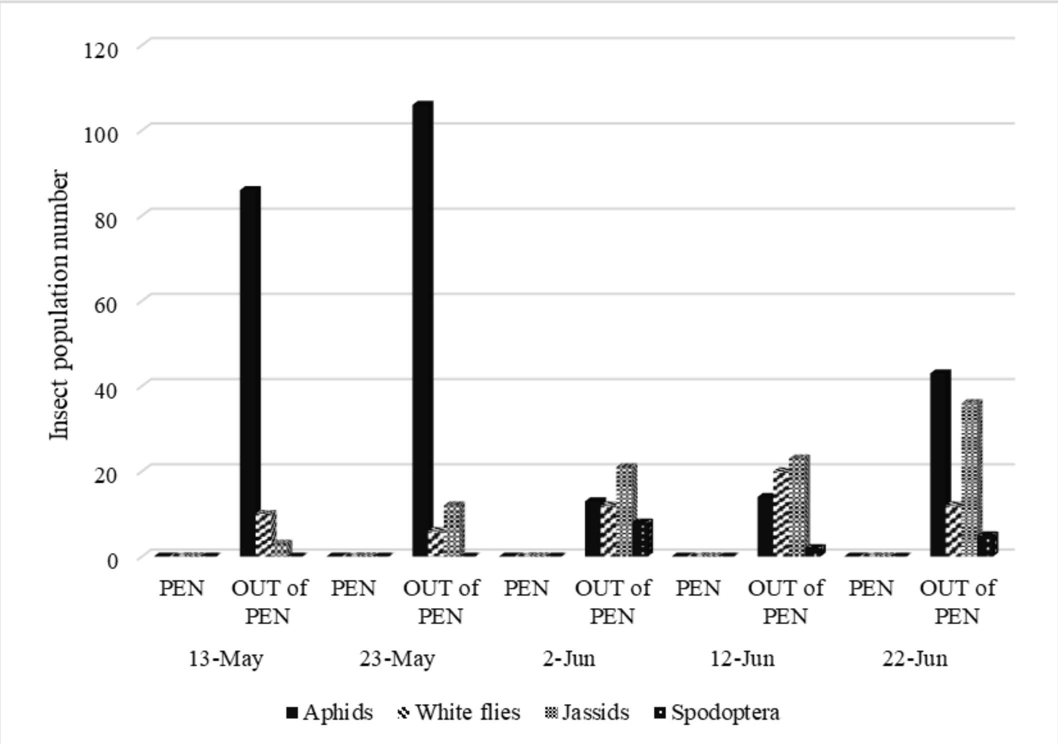


Figure 10. Comparison of different insects pest inside and outside of pest exclusion net during okra production at Rampur, Chitwan, 2018

4.7 Comparison of temperature and relative humidity outside and inside of pest exclusion net

The Figure 11 shows the temperature (^{0}C) inside and outside pest exclusion net during different months of research period. In entire period of research, temperature was found higher outside the pest exclusion net when compare with temperature inside the PEN.

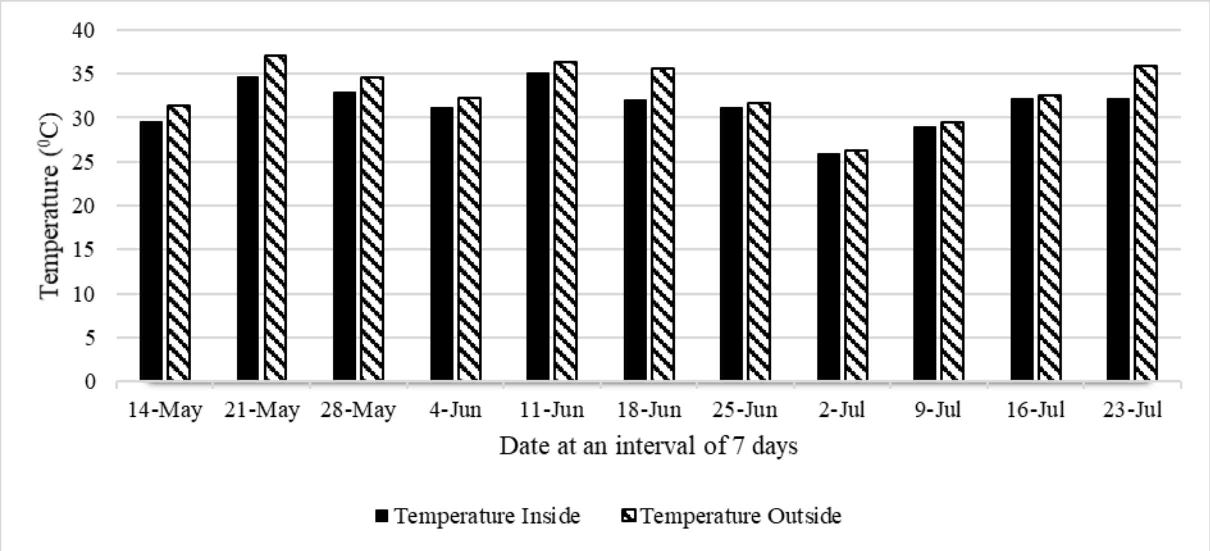


Figure 11. Comparison of atmospheric temperature inside and outside of pest exclusion net during okra production at Rampur, Chitwan, 2018

The Figure 12 shows the comparison of relative humidity (%) inside and outside pest exclusion net during the research period. The relative humidity was found higher inside the pest exclusion net in comparison to open field throughout the research period. This may be due to restriction of air exchange between inside and outside the net house.

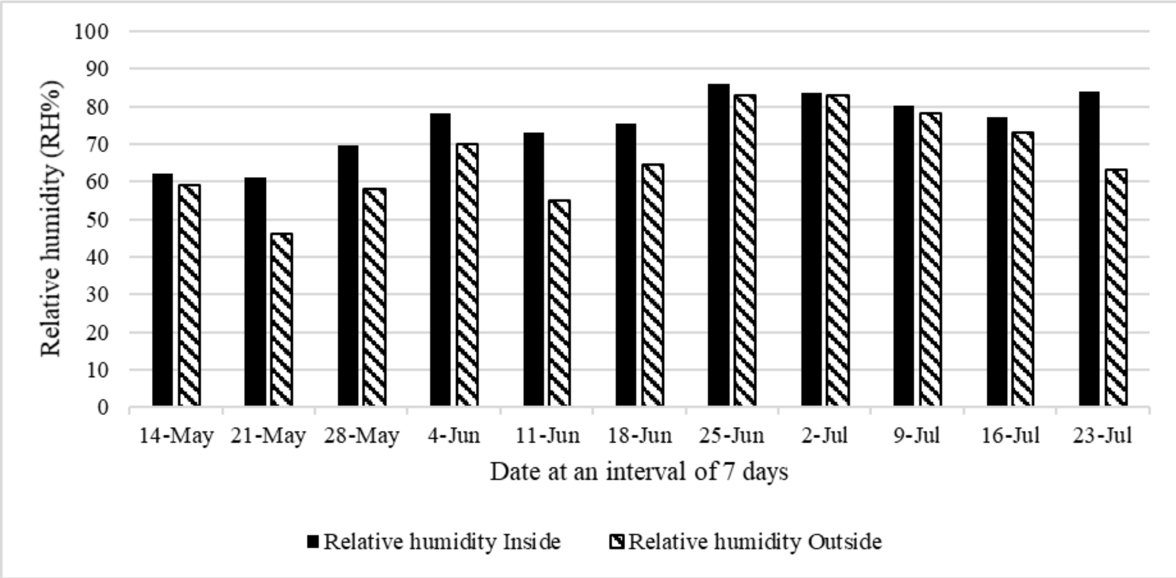


Figure 12. Comparison of relative humidity inside and outside of pest exclusion net during okra production at Rampur, Chitwan, 2018

4.8 Correlation on yield attributing factors

The Table 102 revealed that yield of the okra was positively and significantly correlated with leaf number (0.988/ plant), branch number (0.966/ plant), fruit number (0.972/ plant) and soil temperature (0.909/ plant). Stem diameter, and light intensity also showed high correlation with yield but found non-significant at 5% level of significance. While, yield of the okra was found negatively and significantly correlated with days to 50% flowering (-0.986). Fruit weight, plant height and fruit length were found negatively correlated with yield but non-significantly

Table 102. Correlation among the yield and yield attributing traits and physical parameters of okra at Rampur, Chitwan, 2018

	PH	STD	LFN	DTF	BN	FRTL	FRTD	FNP	ST	LI	FW
TY	-.216	.428	.984**	-.985**	.962**	-.218	.060	.972**	.899*	.777	-.590
PH		.778	-.332	.245	-.310	.967**	.960**	-.032	-.501	-.756	.912*
STD			.332	-.402	.350	.733	.910*	.571	.069	-.192	.473
LFN				-.983**	.987**	-.340	-.067	.929*	.890*	.850	-.670
DTF					-.987**	.215	-.016	-.971**	-.852	-.816	.612
BN						-.293	-.059	.926*	.821	.851	-.645
FRTL							.914*	-.003	-.515	-.707	.867
FRTD								.232	-.243	-.565	.767
FNP									.801	.664	-.437
ST										.838	-.788
LI											-.946*

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
TY= total yield of plot (gm), PH= plant height (cm), STD= stem diameter (mm), LFN= leaf number, DTF= 50% days to flowering, BN=branch number, FRTL=fruit length, FRDL= fruit length, FNP= fruit number per plant, ST= soil temperature (^{0}C), LI= light intensity (lux), FW= pod/fruit weight (gm)

4.9 Economic analysis

The economic analysis was carried out in order to find out more profitable way of cultivation of okra. The benefit cost ratio of okra cultivation under different mulching practice was as shown in Table 113.

Table 113. Benefit cost ratio of okra cultivated with different treatments at Rampur, Chitwan, Nepal, 2018

Treatments	**Total production per ha.**	**Gross return per ha.**	**Cost of cultivation per ha.**	**B:C ratio (Gross return/Total cost incurred)**
Control	22710	908400	633500	1.43
Straw Mulch	24400	976000	733500	1.33
Black Plastic Mulch	29390	1175600	783500	1.50
Silver Plastic Mulch	30740	1229600	783500	1.57
PEN+black Plastic Mulch	20400	816000	1260166.667	0.65

This shows that control, straw mulch, black plastic mulch and silver plastic mulch treatment were economically viable and B:C ratio of PEN+black plastic mulch was non-viable. Among the treatment the most profitable cultivation was found in silver plastic mulch with B:C ratio of 1.57.

5 DISCUSSION

5.1 Effect of pest exclusion net and mulching on physical parameters of okra growing condition

The highest soil temperature among the treatment was recorded with black plastic mulch and the lowest soil temperature was found in PEN+black plastic mulch. Thermal properties (reflectivity, absorptivity, or transmittance) of plastic mulch depends on its color which influence on the microclimate around the vegetable plant (Lament, 1993). Color determines the surface temperature of the mulch and underlying soil temperatures. Black plastic mulch absorbs higher solar radiation that can be transferred to the soil by conduction with good contact between the plastic mulch and soil surface (Kumari, Ojha, & Job, 2016; Lamont, 2005; Snyder et al., 2015). Silver plastic mulch reflects solar radiation which inturn decreases soil temperature. This is in consistent with the findings of Laulina and Hasan (2018). The soil temperature inside pest exclusion net was found lower than that in control condition. Tanny (2013) also supported the result who found that the shading effect of screens reduces the amount of incoming radiant energy, and thus has the potential to reduce the temperature. In this study, straw mulch treated soil had 0.88^{0}C less temperature than of control and; PEN+black plastic mulch had 1.75^{0}C less temperature than of control treatment. The finding was in concurrent with the study of Chen (2007) in winter wheat. Soil temperature during seed germination was also found highest in black plastic mulch and lowest in PEN+black plastic mulch. However, soil moisture percentage was found highest in PEN+black plastic mulch followed by black plastic and silver plastic mulch. In seed germination, it was found that soil moisture content during germination was more proportional to the early germination of seeds which concurrents with the study of Marsh (1993). The early 50% seed germination was obtained from PEN+black plastic mulch.

Moisture stress during periods of intermittent drought was not experienced in the mulched plots which might have accounted for the improved performance of the okra. Similar condition was obtained in the study of Dalorima, Bunu, Kyari, and Mohammed (2014).

Similarly, studies showed that transmissivity of pest exclusion net is low which reduces the transmission of total radiant energy inside PEN (Tanny, 2013). The accumulation of dust particles on PEN further helps to deccrease the transmission of radiant energy. Silver plastic mulches also have the effect of changing the amount and quality of light reflected up into the plant canopy resulting high light intensity for plant (Ham et al., 1993; Hutton &

Handley, 2007). In this study, the light intensity, therefore, is found higher with silver plastic mulching . The light intensity matters in okra yield (Singh, 1994).

The relative humidity was found higher inside the pest exclusion net in comparison to open field throughout the research period. This may be due to restriction of air exchange between inside and outside the net house. Similar result were obtained withthe study of Xu, Liu, Wang, Xiong, and Hang (2017).

5.2 Effect of pest exclusion net and mulching on growth variables of okra

Light intensity, temperature and soil moisture affect vegetative growth of plant (Budania & Dahiya, 2018). Among the different factors, light intensity is also one of the major factors that determines the plant height of same genotypes (Singh, 1994). Among the five treatments, plant height of okra obtained from pest exclusion net combined with black plastic mulch was significantly higher. This result is also supported by the experiment conducted by Neupane, Shrestha, Regmi, Fooyontphanich, and Raj (2018) in broad leaf mustard. Dada and Adejumo (2015) also found high plant height in low light intensity. The higher plant height inside pest exclusion net may be due to the elongation of internodes to capture light in case of low light intensity (Yasoda, Pradheeban, Nishanthan, & Sivachandiran, 2018).

Plant height outside the PEN house was also seen significantly different. Plant height with black plastic mulch, silver plastic mulch and straw mulch were found at par and plant height on control treatment was found low compared to others. Similar findings were found in the study of Mahadeen (2014) and Shivaraj, Balakrishnan, Reddy, Kandpal, and Patil (2018)

Fruit number per plant was found as the highest with silver plastic mulch and lowest in PEN+black plastic mulch. Light intensity might have role in lowering fruit number per plant as flowering number get decreased. However in the study of Dada and Adejumo (2015), fruit number per plant was found high in low light intensity.

Days to 50% flowering was found earlier with black plastic mulch and late with PEN + black plastic mulch. In low light intensity, late flowering was found in the study of Dada and Adejumo (2015) which is concurrent with this study also.

Stem diameter of okra plant from the PEN house was the higher as compared to open field in study of Kakade, Gupta, Patil, and Karne (2018). In this study, stem diameter of control treatment was found as the least and stem diameter inside PEN house was found at par with the stem diameter of plant with silver plastic mulch, black plastic mulch and straw mulch.

Branch number was found as the highest with silver plastic mulch that was at par with black plastic mulch and lowest was found of plant inside PEN house. Since the reflected light also received into dense canopies, silver plastic mulch might have favoured better scattering of light resulting into more availability of photosynthetically active radiation favouring conversion of photosynthesis into higher growth attributes. The crop grown in open field condition registered significantly the highest number of branches per plant. These finding were in the line with other several authors (Ashrafuzzaman, Halim, Ismail, Shahidullah, & Hossain, 2011; Maida, Bisen, & Diwan., 2019).

Fruit weight and its dimension viz. fruit diameter and length, were found the highest of plant with PEN+black plastic mulch. Due to number of fruits per plant and branch number were low, yield of okra inside pest exclusion net with black plastic mulch was found low. However, fruit size was good of pest exclusion net with black plastic mulch.

Early germination was found inside PEN+black plastic mulch, which was at par with silver plastic mulch. The combined effect of soil temperature, moisture content and relative humidity might have affect in early germination okra. Average temperature of soil during okra germination was lowest in PEN+black plastic mulch among all and soil moisture was found highest. Late germination was obtained in control treatment which had high soil temperature combined with low soil moisture content.

Low light intensity, due to net shading of PEN house, promotes vegetative growth reducing the reproductive development resulting low yield (Amarante, Steffens, & Argenta, 2010; Manja & Aoun, 2019). Due to low light interception inside PEN, individual weight of cabbage was found lower inside PEN as compared to outside of PEN (Rahman, 2019) which was similar with this study.

Bastías, Manfrini, and Grappadelli (2012) reported that early in the season, under sunlight limitation, shoot growth is favored over fruit development for photo-assimilate allocation. Rajasekar, Arumugam, Kumar, Balakrishnan, and Krishnasamy (2014) found that vegetables grown under shadenet house had higher yield per plant compared to open field culture, except for cluster bean and okra which had higher yield under field culture.

5.3 Effect of pest exclusion net and mulching on insect infestation of okra

No any insects were found inside the pest exclusion net in present study. Aphids, white flies, jassids and spodoptera were recorded outside of the pest exclusion net. Aphids and jassids were more in number.

6 SUMMARY AND CONCLUSION

The present investigation entitled "Effect of Pest Exclusion Net and Mulching on Okra Production at Rampur, Chitwan, Nepal" was carried out in research field of Agriculture and Forestry University, in 2018 to assess the effect of mulching and protected cultivation of okra crop for yield and quality improvement. The experiment was laid out in a randomized complete block design having four replications and five treatments. Swastik-2 F1 variety was selected for the study. Each plot was of size 8.4 m^2 area. FYM was applied 15 days prior to seed sowing and full dose of DAP, MOP and 30% of urea were applied as basal dose and remaining dose of urea were applied one month after sowing. The field soil was treated with formalin 5 days prior to planting.

Recorded data were analyzed using R-software (R version 3.5.3), Excel 2016 and Minitab 18. Different growth and reproductive parameters like plant height, stem diameter, leaf number per plant, days to flowering fruit length, fruit diameter, fruit weight, branch number, fruit number and yield were recorded. Physical parameters like soil temperature, light intensity, soil moisture were studied.

The result revealed that plants inside the PEN house were taller compared to other treatments. The shortest height was found with control. The highest stem diameter was obtained with silver plastic mulching and the lowest diameter was obtained with control treatment. More or less similar result was found in case of leaf number also. The shortest vegetative period was obtained with silver plastic mulching while the longest period was recorded with PEN+black plastic mulching.

Okra fruit length in case of PEN+black plastic mulching was significantly different than other treatments. The shortest fruit length was obtained with control treatment which was at par with straw mulching and black plastic mulching. Similar result was obtained in case of fruit diameter. Fruit weight was also found as the highest withPEN + black plastic mulching while fruit weight in other treatments were at par.

The highest branching was recorded in silver plastic mulch treated plant (5.1) which was followed by black plastic mulch treated plant (4.8). The lowest branch number was found in the plant cultivated inside PEN+black plastic mulch (3.85). Fruit number per plant was recorded as the highest in plant under silver plastic mulch treatment (33.65) which was followed by plant under black plastic mulch treatment. The lowest fruit number per plant was obtained in PEN+black plastic mulch treated plant (21.88).

Among the five treatments, the highest yield was recorded on the plant cultivated in silver plastic mulch (30.74 mt/ha) which was at par with black plastic mulch treatment (29.39 mt/ha). The lowest yield was recorded on the plant cultivated under PEN+black plastic mulch (20.4 mt/ha) which was at par with control (22.71 mt/ha) and straw mulch (24.4 mt/ha) treatment.

Soil temperature and light intensity (lux) both were recorded lowest inside PEN+black plastic mulch treatment. The highest soil temperature was obtained in Black plastic mulch while the highest light intensity(lux) was obtained in silver plastic mulch.

Hastening of the germination was observed with mulching as 50% of the seed germinated early in treatment: PEN+black plastic mulch (3.75 days after sowing) which was followed by silver plastic mulch (4.5 days after sowing).

Physiological loss in weightwas found as the highest in fruits harvested from PEN+black plastic mulch treatment while the lowest was obtained from the fruit collected from control plot.

Correlation study revealed that yield of okra is positively and significantly correlated with leaf number per plant, branch number per plant, fruit number per plant and soil temperature while yield is negatively and significantly correlated with days to flowering.

Analysis of B:C ratio revealed that sliver plastic mulch and black plastic mulch were economically more viable and profitable compared to other treatment. Bute B:C ratio of PEN+black plastic mulch was non-viable. Among the treatment the most profitable cultivation was found in silver plastic mulch.

In conclusion, leaf number of plant, branch number, fruit number per plant and soil temperature were found highest in black plastic mulch and silver plastic mulch which are highly correlated with yield. Thus it may be recommended that, silver plastic mulch or black plastic mulch is the best for commercial okra production which is more cost effective than PEN+black plastic mulch. However, its further verification is equally important for wider dissemination and recommendation of the technology at particular agro-ecological domain.

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APPENDICES

Appendix 1. Cost of cultivation of okra inside PEN+black plastic mulch

Particular	**Unit**	**No of unit**	**Rate (Rs.)**	**Total Amount (per ropani)**	**Total Amount (per Ha.)**
Tractor	Day	3	1000	3000	60000
Labor for field preparation fertilizer application and weeding	Person	4	800	3200	64000
Okra Seed	gram	750	3.5	2625	52500
Plastic tray	No	60	150	9000	180000
Plastic rope	roll	3	500	1500	30000
Farm Yard Manure	kg	800	5	4000	80000
NPK fertilizer	kg	12	50	600	12000
Formalin	liter	2	400	800	16000
Micronutrient (HB101)	No	5	150	750	15000
Fungicide		2	100	200	4000
Irrigation	Hours	60	100	6000	120000
Black plastic mulch	roll	1.5	5000	7500	150000
Net house*	Sq. m.	650	1100	715000	14300000
Total Amount (in Rs.)				**754175**	**15083500**

*Net house can be used for 30 seasons

So for 1 season, cost of Net house= Rs. 23833.33 per ropani and Rs. 476666.67 per ha. So total amount of cost for PEN+black plastic mulch for a season is: Rs. **63008.33** per ropani and Rs. **1260166.667** per ha.

Appendix 2. Cost of cultivation of okra in silver plastic mulch and black plastic mulch

Particular	**Unit**	**No of unit**	**Rate (Rs.)**	**Total per ropani**	**Total per Ha**
Tractor	Day	3	1000	3000	60000
Labor for field preparation	Person	4	800	3200	64000
Okra Seed	gram	750	3.5	2625	52500
Plastic tray	No	60	150	9000	180000
Plastic rope	roll	3	500	1500	30000
Farm Yard Manure	kg	800	5	4000	80000
NPK fertilizer	kg	12	50	600	12000
Formalin	liter	2	400	800	16000
Micronutrient (HB101)	No	5	150	750	15000
Fungicide		2	100	200	4000
Irrigation	Hours	60	100	6000	120000
Black plastic mulch	roll	1.5	5000	7500	150000
Net house	Sq.m.	0	0	0	0
Total				**39175**	**783500**

Appendix 3. Cost of Production of okra in straw mulch

Particular	Unit	No of unit	Rate (Rs.)	Total per ropani	Total per Ha
Tractor	Day	3	1000	3000	60000
Labor for field preparation	Person	4	800	3200	64000
Okra Seed	gram	750	3.5	2625	52500
Plastic tray	No	60	150	9000	180000
Plastic rope	roll	3	500	1500	30000
Farm Yard Manure	kg	800	5	4000	80000
NPK fertilizer	kg	12	50	600	12000
Formalin	liter	2	400	800	16000
Micronutrient (HB101)	No	5	150	750	15000
Fungicide		2	100	200	4000
Irrigation	Hours	60	100	6000	120000
Straw mulch	kg	1000	5	5000	100000
Net house	Sq. m.	0	0	0	0
Total				**36675**	**733500**

Appendix 4. Cost of production of okra in normal condition (control)

Particular	Unit	No of unit	Rate (Rs.)	Total per ropani	Total per Ha
Tractor	Day	3	1000	3000	60000
Labor for field preparation	Person	4	800	3200	64000
Okra Seed	gram	750	3.5	2625	52500
Plastic tray	No	60	150	9000	180000
Platic rope	roll	3	500	1500	30000
Farm Yard Manure	kg	800	5	4000	80000
NPK fertilizer	kg	12	50	600	12000
Formalin	liter	2	400	800	16000
Micronutrient (HB101)	No	5	150	750	15000
Fungicide		2	100	200	4000
Irrigation	Hours	60	100	6000	120000
Straw mulch	kg	0	0	0	0
Net house	Sq.m.	0	0	0	0
Total				**31675**	**633500**

GLIMPSE OF RESEARCH ACTIVITIES:

Formalin treatment for open field
(Date: 2018-5-03)

Formalin treatment inside PEN house
(Date: 2018-05-03)

Field preparation for seed sowing
(Date: 2018-05-06)

Figure 13. Field inspection by Major advisor
(Date: 2018-05-06)

Monitoring of field

Field visit by Major advisor (Date: 2018-05-25)

Data recording on light intensity (Date:2018-05-28)

Plant height recording

Stem diameter recording

Data recording of produce okra pod

BIOGRAPHICAL SKETCH

The author was born on 17th August, 1992 A.D. (2049/05/01 B.S.) in Dhaijan-04, Jhapa, Nepal as the eldest daughter of Mr. Chopendra Chauhan and Mrs. Tulasha Chauhan. She completed her School leaving certificate (SLC) from Little Angles Boarding School, Jhapa, Nepal. She received her higher secondary degree in science (10+2) from Nicholson Higher Secondary School, Bhaktpur, Nepal. She got government scholarship to study bachelor degree in agriculture science in Institute of Agriculture and Animal Science, Rampur Campus, TU, Nepal. She got an opportunity to pursue B.Sc.Ag. degree majoring Undergraduate Practicum Assessment course in Agronomy and completed the degree in 2015 A.D. After completion of bachelor degree, she got enrolled in Agriculture and Forestry University for master's degree in agriculture science. She got married to Mr. Shree Krishna Adhikari on 10th July, 2018. She is gentle and diligent person with strong will power. She has attained some profession related trainings and workshop during her study. She wishes to serve the nation through her excellence and hard work.

Swastika Chauhan