Technology in Horticulture

ARTICLE

Open Access

https://doi.org/10.48130/tihort-0024-0009

Technology in Horticulture **2024**, 4: e012

Evaluating the impact of mulching and fertilizer combinations in maximizing cucumber (*Cucumis sativus* L.) growth and production

Milan Acharya, Sudip Ghimire* and Nabin Gautam

Faculty of Agriculture, Agriculture and Forestry University, Rampur, Chitwan 44200, Nepal

* Corresponding author, E-mail: ghimiresudip858@gmail.com

Abstract

Efficient cucumber cultivation requires a thorough understanding of the interplay between cultivation practices and crop productivity. This study, conducted from February to June 2022 in Nawalparasi district, Nepal, addresses the challenge of optimizing cucumber production through an exploration of the combined effects of mulching and various fertilizer applications. The research aimed to evaluate the hypothesis that specific mulching and fertilizer combinations would lead to superior growth and yield in cucumber plants. The experimental design employed a two-factorial Randomized Complete Block Design (RCBD) with two mulching conditions (mulching and non-mulching) and four different fertilizers [Control, Farmyard manure (FYM), and NPK treatments consisting of Nitrogen (N), Phosphorus (P), and Potassium (K) applied at a rate of 140:40:100 NPK/ha), and FYM + NPK, resulting in eight treatment combinations replicated three times. The results revealed that plastic mulching significantly enhanced key growth parameters, including plant height (170.80 cm), number of branches (5.35), number of leaves (51.96), and yield (25.93 t/ha) of cucumber, compared with the no-mulch treatments. Notably, the application of FYM in conjunction with NPK exhibited optimal outcomes for plant height (181.23 cm), number of leaves (52.50), yield (27.97 t/ha), and highest benefit-cost ratio (2.60). The study recommends adopting mulching over no-mulching and utilizing a combination of FYM and NPK fertilizers for enhanced cucumber growth and economically viable yields. Despite the positive outcomes, it is imperative to conduct the test on a larger scale for a more comprehensive evaluation.

Citation: Acharya M, Ghimire S, Gautam N. 2024. Evaluating the impact of mulching and fertilizer combinations in maximizing cucumber (*Cucumis sativus* L.) growth and production. *Technology in Horticulture* 4: e012 https://doi.org/10.48130/tihort-0024-0009

Introduction

Cucumber (*Cucumis sativus* L.) holds economic significance as a popular vegetable in the terai and hill regions of Nepal. Rich in vitamins C and K, along with other essential nutrients and antioxidants, cucumber is not only a staple raw vegetable but also a processed product known for its hydrating and skin-soothing properties[1,2]. Despite its high yield potential, cucumber cultivation faces challenges, including sensitivity to frost and the prevalence of specific landraces with suboptimal characteristics. Nepal boasts diverse cucumber landraces, with varieties like *Cucumis bardiwikii* found in the hills. However, challenges arise, especially during the summer wet season, as certain commercial cultivars, such as Green long and Pointsett, and underperform due to the prevalence of male flowers.

Fertilizer plays a pivotal role in cucumber production, constituting a significant portion of production costs[3]. Cucumber's high fertilizer demand necessitates precise nutrient management to achieve optimal yields and fruit quality[4,5]. Soil fertility, type, and cultural practices all influence the nutritional requirements of cucumber. In this context, the appropriate application of farmyard manure (FYM) and recommended doses of nitrogen, phosphorus, and potassium (NPK) becomes crucial[6]. Mulching, whether organic or plastic, offers a multifaceted approach to enhance cucumber cultivation[7−9]. It aids in moisture conservation, temperature control, weed suppression, runoff reduction, erosion prevention, and soil structure improvement[10]. Mulching protects plant roots from environmental stresses and keeps fruits clean by preventing direct contact with the soil[11,12]. Studies suggest that cucumber plants on black plastic mulch with a white perforated row cover yield earlier and higher than those in bare soil, indicating the potential of mulching in cucumber cultivation[13]. The use of mulch has been associated with reduced weed growth, resulting in lower herbicide application and overall production costs[14]. Additionally, mulching influences soil temperature, with black plastic mulch absorbing the majority of incoming sun radiation, trapping it in the soil's top layer and causing it to heat up[14]. However, despite the potential advantages of mulching and precise fertilizer application, there is a gap in knowledge regarding their combined effects on cucumber growth and yield.

Cucumber cultivation holds significant economic potential, but the associated challenges, such as high labor costs, weed management, and frequent herbicide applications, necessitate effective strategies[15]. Recognizing the influence of nitrogen, phosphorus, and potassium on cucumber growth, coupled with the benefits of mulching, this study aimed to provide insights into a holistic approach to improving cucumber production. Nepal faces challenges in cucumber production, with lower yields compared to the global average. The cultivation of local, long-duration varieties, limited awareness of hybrid varieties, and insufficient knowledge about mulching practices contribute to these issues. Additionally, inadequate fertilizer application, especially neglecting the recommended doses of NPK, further hampers cucumber yield. This study aimed to address this gap by investigating the performance of cucumber under different mulching conditions and fertilizer applications. The study hypothesized that the combined application of mulching and recommended doses of FYM and NPK fertilizer would significantly enhance cucumber growth and yield compared to conventional farming practices. The objective of this study was to assess the combined impact of mulching and fertilizer application, specifically FYM and NPK, on the growth parameters and yield of cucumber to provide comprehensive insights into enhancing cucumber cultivation practices to the scientific community, filling gaps in knowledge related to cucumber cultivation practices, thereby facilitating informed decision-making in agriculture.

Materials and methods

Experimental site and soil condition

The study was conducted during the period from February 2022 to June 2022 in Ramgram-17, Mahuwari, located in Nawalparasi (Bardaghat Susta West), falling under the jurisdiction of the Agriculture Knowledge Centre (AKC), Nawalparasi West, Nepal. Geographically, the study site is positioned at 27°32'N latitude and 83°40'E longitude, with an elevation of 119 m above sea level.

During the initial phase of the research activity, soil samples were systematically collected from the field at a depth of 0 to 15 cm using a hoe and shovel, employing a Z-shaped soil sampling technique. Subsequently, the soil samples underwent comprehensive analysis to determine their status, as outlined in Table 1. The soil analysis was conducted by technical personnel at the Soil and Fertilizer Testing Laboratory in Khajura, Banke, Nepal. Specifically, nitrogen content was determined through Kjeldhal distillation[16], phosphorus levels were assessed using the ammonium acetate method[17], and organic matter content was analyzed following the Walkley & Black method[18], as followed by Ghimire et al.[19]. Additionally, the pH levels were measured using a Beckman Glass electrode pH meter, while soil texture was determined through the hydrometer method[20].

Analysis of the obtained soil data revealed that the soil at the study site exhibited a slightly alkaline pH and a clayey loam texture. Additionally, the levels of essential macro-nutrients and organic matter were observed to be relatively low. In light of these findings, the Ministry of Agriculture and Livestock Development[21] recommended the application of the standard dose of NPK along with 29,475 kg/ha of FYM to enhance and maintain the nutritional status of the soil.

Experimental details

The research was conducted using two-factor Randomized Complete Block Design (RCBD) involving eight treatment combinations, each replicated three times. The focus of the study was the cultivation of cucumber, specifically the Raja (F1 Hybrid) variety, with a designated plant spacing of 75 cm × 75 cm. The selected treatments comprised a combination of mulching and non-mulching factors (Factor A) with varying nutrient applications (Factor B), as outlined in Table 2. The treatments included mulching and non-mulching (T_1 and T_5, respectively), as well as combinations of mulching with FYM (30 t/ha), the recommended dose of fertilizer (RDF) of NPK (140:40:100 NPK/ha), and a combination of FYM and NPK. The field layout comprised a total of 24 plots in RCBD (Fig. 1). Each plot covered a net area of 9 m², resulting in an overall experimental area of 283.5 m². Within each plot, a systematic arrangement of 16 cucumber plants was made, including observational and border plants. The experimental plots were strategically spaced with 0.5 m between treatments and 0.75 m between replications, while a 1 m border area on all sides ensured isolation from other crops. This layout aimed to facilitate a comprehensive assessment of the impact of mulching and nutrient treatments on cucumber growth and yield. The cucumber seeds, mulching materials, and fertilizers were obtained from Dikshya Agrovet in Nawalparasi West, Nepal. These items exhibit consistent quality and size.

Table 1. Soil nutritional condition of the study site.

S. N	Soil status	Values
1	Textural class	Clay loam (Alluvial)
2	Chemical properties	
i	p^H	7.6 (Alkaline)
ii	Nitrogen (%)	0.09 (Low)
iii	Phosphorus (kg/ha)	(Low)
iv	Potassium (kg/ha)	(Low)
v	Organic matter (%)	1.95 (Low)

Table 2. Treatment details used in the experiment.

Treatment	Details
$T_{1\ (M1F0)}$	Mulching and control (without fertilizer)
$T_{2\ (M1F1)}$	Mulching and FYM only
$T_{3\ (M1F2)}$	Mulching and RDF of NPK
$T_{4\ (M1F3)}$	Mulching and combination of FYM and NPK
$T_{5\ (M2F0)}$	Non-mulching and control
$T_{6\ (M2F1)}$	Non-mulching and FYM only
$T_{7\ (M2F2)}$	Non-mulching and RDF of NPK
$T_{8\ (M2F3)}$	Non-mulching and combination of FYM and NPK

RDF stands for Recommended dose of fertilizer (For NPK = 140:40:100 NPK/ha; For farmyard manure = 30 t/ha).

Plantation and crop management

Field preparation

The field underwent thorough preparation to ensure an optimal transplanting environment. The initial plowing was executed using a rotavator attached to a tractor. Subsequently, the field was measured with precision using a tape measure to guarantee adequate land allocation for the research. After completing the layout, plots and replications were demarcated using a hoe (*kodali*), forming ridges and furrows. Silver-coated mulching plastic of 0.003 cm thickness covered the ridges, while furrows were designated for irrigation purposes. Each 9 m^2 plot was divided into four rows, necessitating the adjustment of the 1.5 m-wide mulching plastic. Holes in the mulching were pre-made a day before transplanting using a circular hot metal instrument, and individual pits with a depth of 30 cm were dug using a *kuti* for cucumber transplantation. The entire field layout followed the predetermined plan.

Seedling preparation, manuring and fertilizer

The Raja variety of cucumber was selected for the study. Raja F1 is a hybrid variety of cucumber. It produces attractive green fruits with a weight ranging from 200 to 250 g and a length of 18 to 20 cm. The variety has a relatively short time to first harvest, with fruits ready for picking in about 40 to 45 d after planting. Raja F1 exhibits good tolerance to diseases and environmental extremes, making it suitable for cultivation in various conditions. Its seeds were planted in a soil-FYM mixture under protected conditions. This was done using poly bags measuring 10.16 cm × 12.7 cm, with the sowing taking place on March 1st. A total of 384 seedlings were required for the

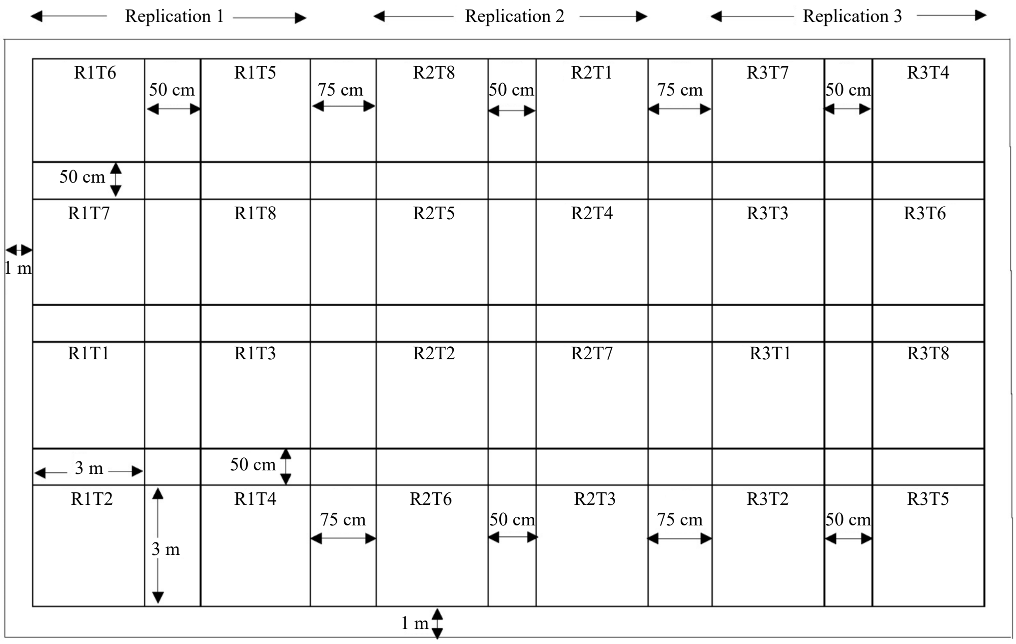

Fig. 1 Experimental layout of the field.

research, and approximately 450 poly bags were prepared to compensate for potential germination and post-transplantation losses. The seedlings were grown in a soil and FYM mixture (2:1 ratio), with Bavistin (1 g/kg of soil) used as a fungicide. After 16 d of germination, seedlings at the 3–4 leaf stage were transplanted during the evening to prevent wilting on March 16th.

The basal dose included FYM, half dose of urea, and full doses of Di-Ammonium Phosphate (DAP) and Muriate of Potash (MoP). The remaining urea was applied in two split doses at 15 and 30 d after transplanting (DAT). Well-decomposed FYM was incorporated into the soil 2–3 d before transplanting. The maturation of farmyard manure occurred following a decomposition period of five months. The FYM consisted of 1.33% total N, 0.23% available P, 0.5% K_2O, 2.38% exchangeable K, 0.14% exchangeable Iron (Fe), 0.78% exchangeable Calcium (Ca), and 0.38% exchangeable Magnesium (Mg). The recommended dose of fertilizer (RDF) per plot was 26.54 kg FYM, 123.84 g urea, 35.38 g Di-Ammonium Phosphate [$(NH_4)_2HPO_4$], and 88.45 g Muriate of Potash (KCl)[22]. Additionally, a mixture of 1 L of cow urine diluted in 10 L of water, known for its properties to control various pests and diseases, was sprayed on the plants one week after transplanting as a biopesticide and antifungal agent.

Cucumber cultivation utilized a 1.5 m trellis method with bamboo stakes for structural support and bamboo sticks for vine training. The trellis system optimized space, improved air circulation, and facilitated vertical growth. Additionally, 3G cutting, a chemical-free pruning technique promoting femaleness and encouraging the growth of third-generation branches was employed to increase overall yield by reducing the male-to-female flower ratio. These practices were intentionally designed to align with local agricultural standards.

Gap filling, weeding, irrigation, disease and pest management

Gap filling was conducted within 1–2 d as required to replace transplanted seedlings that died due to various stresses and climatic conditions. Manual weeding was performed in non-mulched plots during the 2nd and 3rd weeks after transplanting, while mulching effectively controlled weed infestation, proving to be a cost-effective method. Pump sets were utilized for irrigation, and furrow channels were constructed between plots for water distribution. Due to the hot climatic conditions, irrigation was carried out at one-week intervals, considering the frequent need for water. Disease and pest management practices were implemented based on the intensity and infestation levels. Cypermethrin and Chlorpyriphos mixture (Rhino 505) at 1 mL/L of water was sprayed three times at one week intervals after they reached marketable size for managing the red pumpkin beetle, and yellow sticky traps were deployed for aphids and whiteflies. Mulching efficiently addressed wilting issues, whereas plants in plots without mulching experienced earlier wilting.

Harvesting

Multiple manual harvests were performed on alternate days when the fruits were in their green stage, attaining a marketable size of approximately 20–25 cm in length and 200–250 g in weight. This ensured that none of the fruits reached an oversized state, and harvesting was conducted throughout the entire crop season. Harvest maturity was ascertained by the spines of the fruits falling upon slight palm pressure and the absence of yellowish color development. It is noteworthy that only marketable fruits were recorded under fruit yield, and any fruits deemed unmarketable were promptly discarded during harvesting.

Observation parameters

Growth parameters (plant height, number of branches, number of leaves)

The measurement of plant height, recorded in centimeters (cm) from the base to the tip, was conducted on four sample plants 15 DAT, using a meter scale or measuring tape. Subsequent measurements were taken at 15-d intervals throughout the growing period to calculate the mean height of the plant. The number of branches per plant was determined for sample plants, and the average was calculated. Measurements were initiated 15 d after transplanting and continued at regular 15-d intervals until harvesting. The total number of leaves on the main stem and branches of sample plants were meticulously counted in each plot, and the average leaf count was calculated.

Yield parameters [number of fruits set per plant, average fruit length, average fruit diameter, fruit yield (kg/plant), fruit yield (kg/plot) and yield (t/ha)]

The number of fruits set per plant was documented, recorded at the time of harvesting from tagged/selected sample plants and average data were calculated. The average length of fruits from sample plants was measured from the head end to the blossom scar end using a centimeter scale, and the average length was calculated for each plot. The average circumference of fruits from sample plants was measured at the center girth using a thin plastic rope and a centimeter scale. The average value was calculated, and the diameter was obtained using a formula for each fruit per plant.

Fruit yield (kg/plant) was determined by weighing the harvested fruits at different pickings using a portable weighing machine. The total weight of all picked fruits during the season from a single plant provided the yield per plant. The fruit yield (kg/plot) was recorded by taking the average weight of fruits from sample plants using a portable digital balance, and the average value was calculated for each plot by weighing the fruits harvested in different pickings. The fruit yield per plot was determined by the total weight of all harvested fruits, specifically focusing on marketable ones; non-marketable fruits, which were discarded during harvesting, were not considered in the calculation of fruit yield. The fruit yield (t/ha) was recorded by weighing the fruits harvested in different pickings, and the total weight of all picked fruits during the season per plot was determined. The fruit yield per plot was then converted into yield per hectare.

Economic analysis

Economic analysis provides a comprehensive understanding of the financial implications of various cultivation practices, aiding decision-making for cucumber growers and agricultural stakeholders. Total production costs for each treatment were calculated by summing up all expenses incurred during the crop cultivation process[23]. This included costs associated with seeds, fertilizers, mulching materials, labor, irrigation, pest control, and any other operational expenses (Eqn 1).

$$\text{Total production cost} = \sum \text{All expenses incurred during cultivation process (Seed + Sertilizers + Mulching materials + Labor + Irrigation + Pest control + Other operational expenses)} \quad (1)$$

Gross returns were determined by multiplying the yield of cucumbers obtained from each treatment by the prevailing market price per kg of cucumber i.e. NRs 20/kg (Eqn 2). Net returns were calculated by subtracting the total production costs from the gross returns, as illustrated by Thapa et al.[24], Ghimire & Rauniyar[25] and Yadav et al.[26] (Eqn 3).

$$\text{Gross return} = \text{Yield (kg)} \times \text{Price per kg of cucumber (NRs. 20)} \quad (2)$$

$$\text{Net return} = \text{Gross return} - \text{Total production cost} \quad (3)$$

The benefit-cost ratio (BCR) was calculated for each treatment to assess its economic profitability. The BCR was obtained by dividing the net returns by the total production costs[6,23,24,26] (Eqn 4). A BCR greater than 1 indicates that the benefits outweigh the costs, making the treatment economically viable.

$$\text{BCR} = \frac{\text{Net benefit}}{\text{Total production costs}} \quad (4)$$

Statistical analysis

The acquired data were organized and tabulated using MS-Excel 2010 (Microsoft Corp., Washington, USA). Statistical analysis was conducted using R-studio (version R-3.6.3) to assess the statistical significance of the obtained data. The means for all treatments were computed, and analysis of variance (ANOVA) for each parameter was executed through the 'F' (variance ratio) test. The significance of differences among the means was determined using Duncan's Multiple Range Test (DMRT) at a 5% level of significance.

Results

Growth parameters

Plant height (cm)

Plant height was significantly different across all treatments and at all observed days after transplanting, as illustrated in Table 3. The measurements were taken at 15, 30, and 45 DAT. Mulching exhibited the highest mean plant heights of 33.98, 143.10, and 170.80 cm at 15, 30, and 45 DAT, respectively, followed by non-mulching with heights of 29.92, 128.81, and 149.16 cm at the corresponding time points. Regarding fertilizers, the combination of FYM and NPK resulted in the maximum plant heights, measuring 36.04, 158.66, and 181.23 cm at 15, 30, and 45 DAT, respectively, followed by NPK with heights of 31.98, 140.29, and 167.77 cm at the respective time points. In contrast, the control group exhibited the minimum plant height.

Table 3. Effect of mulching and fertilizers on plant height of cucumber.

Treatment	Plant height (cm)		
	15 DAT	30 DAT	45 DAT
Factor A			
Mulching	33.98^a	143.10^a	170.80^a
Non-mulching	28.92^b	128.81^b	149.16^b
LSD (0.05)	2.63	3.03	3.033
SEM (±)	0.43	0.93	0.8
F-test	**	***	***
CV (%)	9.55	4.74	3.45
Factor B			
Control	27.29^c	119.0^c	141.20^d
FYM	30.50^{bc}	125.87^c	149.74^c
NPK	31.98^b	140.29^b	167.77^b
FYM + NPK	36.04^a	158.66^a	181.23^a
LSD (0.05)	3.72		3.033
SEM (±)	0.31	0.66	0.56
F-test	**	***	***
CV (%)	9.55	4.74	3.45
Grand mean	31.45	135.96	159.98
A × B			
F-test	NS	NS	**

DAT = Days after transplanting; Data in columns with the same letters in DMRT are not significantly different (p = 0.05); SEM (±) = Standard error of the mean; CV = Coefficient of variation; LSD = Least significant difference; ** = significant at $p < 0.01$; *** = significant at $p < 0.001$.

Table 4 provides a detailed overview of the interaction of different treatments, namely mulching and non-mulching, and various fertilizer applications on cucumber height at 45 DAT. Under the mulching condition, the highest mean plant height was observed for the FYM + NPK treatment at 196.25 cm, followed by NPK (184.89 cm), FYM (156.39 cm), and control (145.69 cm). In the non-mulching category, similar trends were observed, with the FYM + NPK treatment producing the highest height at 166.21 cm, followed by NPK (150.66 cm), FYM (143.08 cm), and control (136.71 cm). The statistical parameters provided further enhance the interpretation of the results. The standard error of the mean (SEM) is minimal (0.4), indicating a high precision in the sample mean estimates. The height of the plant was not influenced significantly due to the effect of the interaction between mulching and fertilizer at 15 and 30 DAT.

Table 4. Interaction effect of mulching and fertilizer on plant height at 45 DAT.

Plant height (cm) at 45 DAT		
Treatments	Mulching	Non-mulching
Control	145.69^{ef}	136.71^{f}
FYM	156.39^{d}	143.08^{ef}
NPK	184.89^{b}	150.66^{de}
FYM + NPK	196.25^{a}	166.21^{c}
SEM (±)	0.4	
LSD (0.05)	9.68	
F-test	**	
CV (%)	3.45	
Grand mean	159.98	

DAT = Days after transplanting; Data in columns with the same letters in DMRT are not significantly different (p = 0.05); SEM (±) = Standard error of the mean; CV = Coefficient of variation; LSD = Least significant difference; ** = significant at p < 0.01.

Number of branches

The investigation into the number of branches in cucumber plants revealed intriguing dynamics over time and across different treatments (Table 5). Initially, at 15 DAT, no significant differences were observed in the number of branches between mulching and fertilizer applications. However, as the study progressed, distinct variations emerged among the treatments. Mulching consistently demonstrated a positive impact on the development of branches, exhibiting the highest numbers at both 30 DAT (4.7 branches) and 45 DAT (5.35 branches). In contrast, non-mulching treatments showed slightly lower numbers, with 3.43 branches at 30 DAT and 4.29 branches at 45 DAT.

Regarding fertilizer applications, a nuanced pattern unfolded. While there were no significant differences in the number of branches at later stages of growth, the FYM treatment consistently outperformed others, yielding higher results. Specifically, at 30 and 45 DAT, the FYM application resulted in 4.29 and 5.41 branches, respectively. In contrast, the control group exhibited the lowest number of branches, with 4.02 at 30 DAT and 4.47 at 45 DAT. The branch number was not influenced significantly due to the effect of the interaction between mulching and fertilizer at any stage of growth.

These findings highlight the intricate interplay between mulching, fertilizer application, and the development of branches in cucumber plants. Mulching consistently contributed to a higher number of branches, while FYM application showed a positive influence in later stages, emphasizing the importance of these factors in optimizing cucumber plant morphology. The absence of significant differences in some instances underscores the need for a nuanced understanding of the temporal and treatment-specific effects on cucumber growth parameters.

Table 5. Effect of mulching and fertilizers on number of branches of cucumber.

Treatment	Number of branches		
	15 DAT	30 DAT	45 DAT
Factor A			
Mulching	1.50	4.70^{a}	5.35^{a}
Non-mulching	1.79	3.43^{b}	4.29^{b}
LSD (0.05)	0.30	0.21	0.429
SEM (±)	0.05	0.04	0.07
F-test	NS	***	***
CV (%)	21.09	6.13	10.17
Factor B			
Control	1.58	4.02^{ab}	4.47^{b}
FYM	1.50	4.29^{a}	5.41^{a}
NPK	1.70	4.16^{a}	4.81^{ab}
FYM + NPK	1.79	3.79^{b}	4.58^{b}
LSD (0.05)	0.43	0.309	0.607
SEM (±)	0.04	0.03	0.05
F-test	NS	*	*
CV (%)	21.09	6.13	10.17
Grand mean	1.64	4.06	4.82
A × B			
F-test	NS	NS	NS

DAT = Days after transplanting; Data in columns with the same letters in DMRT are not significantly different (p = 0.05); SEM (±) = Standard error of the mean; CV = Coefficient of variation; LSD = Least significant difference; * = significant at p < 0.05; NS = Non-significant.

Number of leaves

In the analysis focusing on mulching, a significant impact on the number of leaves per cucumber plant was observed. At 15 DAT, mulching exhibited the highest number of leaves, recording 4.89 leaves per plant. This trend continued at 30 DAT, with an increased number of leaves (39.62 per plant), and further escalated at 45 DAT, reaching 51.96 leaves per plant (Table 6).

The influence of different fertilizer applications on the number of leaves unfolded distinctively. At 15 DAT, no significant difference was observed among the fertilizer treatments. However, as the study progressed, nuanced variations emerged. At 30 DAT, subtle differences were noted, and by 45 DAT, a significant contrast was evident. The treatment combining FYM and NPK displayed the highest number of leaves, reaching 52.50 leaves per plant, followed by FYM alone, which recorded 45.29 leaves per plant. The leaves number was not influenced significantly due to the effect of the interaction between mulching and fertilizer at any stage of growth. These findings underscore the differential impact of mulching and fertilizer treatments on the foliage development of cucumber plants. Mulching consistently demonstrated a positive influence on leaf numbers, while the combination of FYM and NPK proved particularly effective in enhancing leaf production in the later stages of plant growth. The nuanced dynamics within Factor B highlight the importance of considering the specific combination of fertilizers for optimizing cucumber plant leaf morphology.

Table 6. Effect of mulching and fertilizers on number of leaves of cucumber.

Treatment	Number of leaves		
	15 DAT	30 DAT	45 DAT
Factor A			
Mulching	4.89[a]	39.62[a]	51.96[a]
Non-mulching	4.18[b]	27.20[b]	37.96[b]
LSD (0.05)	0.29	3.67	3.35
SEM (±)	0.05	0.61	0.55
F-test	***	***	***
CV (%)	7.51	12.55	8.52
Factor B			
Control	4.45[ab]	29.12[b]	38.08[c]
FYM	4.70[a]	35.04[a]	45.29[b]
NPK	4.75[a]	32.54[ab]	43.96[b]
FYM + NPK	4.25[b]	36.95[a]	52.50[a]
LSD (0.05)	0.42	5.19	4.74
SEM (±)	0.03	0.43	0.39
F-test	NS	*	***
CV (%)	7.51	12.55	16.89
Grand mean	4.54	33.41	44.96
A × B			
F-test	NS	NS	NS

DAT = Days after transplanting; Data in columns with the same letters in DMRT are not significantly different (p = 0.05); SEM (±) = Standard error of the mean; CV = Coefficient of variation; LSD = Least significant difference; * = significant at $p < 0.05$; *** = significant at $p < 0.001$; NS = Non-significant.

Yield parameters

Fruit set, fruit length and fruit diameter

The investigation into fruit-related parameters in cucumber plants revealed significant variations influenced by both mulching (Factor A) and different fertilizers (Factor B), as illustrated in Table 7. In terms of mulching, a substantial impact was observed in fruit set per plant, with mulched plants exhibiting a significantly higher mean value of 13.73 compared to non-mulched plants at 10.82. Mulching also influenced fruit length, where mulched plants had longer fruits (20.68 cm) compared to non-mulched plants (19.28 cm). However, the effect on fruit diameter was not statistically significant. Concerning fertilizers, the combination of FYM and NPK resulted in the highest fruit set per plant (14.68), followed by NPK (12.26) and FYM (12.16), while the control group had the lowest fruit set (9.99). The control group had the longest fruits (20.54 cm), followed by FYM + NPK (19.86 cm), NPK (19.33 cm), and FYM (20.21 cm). Notably, no significant differences were observed in fruit diameter among fertilizer treatments. The fruit set, fruit length and fruit diameter was not influenced significantly due to the effect of the interaction between mulching and fertilizer.

Yield per plant and yield per hectare

The analysis of cucumber yield per plant and hectare revealed significant effects attributed to both mulching (Factor A) and various fertilizer applications (Factor B), as shown in Table 8. Mulching exhibited a substantial impact, with mulched plants yielding significantly higher, both per plant (1,047.43 g) and per hectare (25.93 t/ha), compared to non-mulched plants, which yielded 673.33 g/plant and 18.37 t/ha. The LSD (0.05) values of 164.45 and 3.27 for yield per plant and per hectare, respectively, emphasized the statistical significance of these differences. The coefficient of variation (CV) indicated the reliability of the data, with values of 21.82% for yield per plant and 16.87% for yield per hectare. In the context of fertilizer application, the combination of FYM and NPK resulted in a higher yield per plant (1,033.74 g), which was statistically similar to the control (878.93 g). Similarly, the combination of FYM and NPK led to a higher yield per hectare (27.97 t/ha), comparable to the yield achieved with FYM alone (23.71 t/ha). The LSD (0.05) values of 232.57 and 4.62 for yield per plant and per hectare, respectively, signified the significance of differences among fertilizer treatments. The yield was not influenced significantly due to the effect of the interaction between mulching and fertilizer.

Table 7. Effect of mulching and fertilizers on fruit set, fruit length and fruit diameter of cucumber.

Treatment	Fruit set/plant	Fruit length (cm)	Fruit diameter (cm)
Factor A			
Mulching	13.73[a]	20.68[a]	5.29[a]
Non-mulching	10.82[b]	19.28[b]	5.23[a]
LSD (0.05)	1.06	1.19	0.41
SEM (±)	0.17	0.20	0.07
F-test	***	NS	NS
CV (%)	9.94	6.85	9.02
Factor B			
Control	9.99[c]	19.33	5.20
FYM	12.16[b]	20.21	5.25
NPK	12.26[b]	19.86	5.27
FYM + NPK	14.68[a]	20.54	5.31
LSD (0.05)	1.51	1.69	0.59
SEM (±)	0.122	0.14	0.05
F-test	**	NS	NS
CV (%)	9.94	6.85	9.01
Grand mean	12.27	19.98	5.26
A × B			
F-test	NS	NS	NS

Data in columns with the same letters in DMRT are not significantly different (p = 0.05); SEM (±) = Standard error of the mean; CV = Coefficient of variation; LSD = Least significant difference; ** = significant at $p < 0.01$; *** = significant at $p < 0.001$; NS = Non-significant.

Table 8. Effect of mulching and fertilizers on yield of cucumber.

Treatment	Yield/plant (g)	Yield (t/ha)
Factor A		
Mulching	1,047.43[a]	25.93[a]
Non-mulching	673.33[b]	18.37[b]
LSD (0.05)	164.45	3.27
SEM (±)	27.10	0.54
F-test	***	***
CV (%)	21.82	16.87
Factor B		
Control	878.93[ab]	14.53[c]
FYM	783.72[b]	23.71[ab]
NPK	745.14[b]	22.39[b]
FYM + NPK	1,033.74[a]	27.97[a]
LSD (0.05)	232.57	4.62
SEM (±)	19.169	0.38
F-test	*	***
CV (%)	21.82	16.87
Grand mean	860.38	22.15
A × B		
F-test	NS	NS

Data in columns with the same letters in DMRT are not significantly different (p = 0.05); SEM (±) = Standard error of the mean; CV = Coefficient of variation; LSD = Least significant difference; * = significant at $p < 0.05$; *** = significant at $p < 0.001$; NS = Non-significant.

Economic analysis of cucumber production

The use of mulching resulted in a significantly higher yield of 25.93 t/ha compared to non-mulching (18.37 t/ha). The total cost of production for mulching was NRs. 154,500 (1 USD$ = 132.37 NRs), with a gross return of NRs. 518,600, leading to a net return of NRs. 364,100 and a benefit-cost ratio (BCR) of 2.35. The positive net return and higher BCR indicate the economic viability of mulching for maximizing cucumber production. In contrast, the non-mulching treatment showed a lower yield of 18.37 t/ha and a net return of NRs. 246,900, with a BCR of 2.04 (Table 9). Although the non-mulching treatment is economically viable, mulching appears to be a more profitable option.

The control treatment resulted in a yield of 14.53 t/ha, with a net return of NRs. 165,100 and a BCR of 1.31. This treatment represents the baseline scenario without additional inputs. The application of FYM resulted in a higher yield of 23.71 t/ha, a net return of NRs. 335,897, and a BCR of 2.42. FYM proves to be an economically beneficial input. The use of NPK fertilizer resulted in a yield of 22.39 t/ha, a net return of NRs. 305,300, and a BCR of 2.14. This treatment demonstrates the economic viability of using chemical fertilizers. The combination of FYM and NPK showed the highest yield of 27.97 t/ha, with a net return of NRs. 404,097 and a BCR of 2.60. This suggests a synergistic effect of combining organic and inorganic inputs, resulting in enhanced economic returns. Both mulching and the combination of FYM and NPK prove to be economically advantageous strategies for maximizing cucumber growth and production, as indicated by their higher net returns and BCRs compared to alternative treatments.

Discussion

The observed variations in cucumber growth and yield parameters across different treatments can be explained by the specific influences of mulching and fertilizer applications on various physiological and environmental factors affecting plant growth. The synergistic combination of mulching and the application of farmyard manure along with NPK in the form of fertilizer (FYM + NPK) has proven to be a highly effective strategy for achieving the highest cucumber yield in the study.

Mulching, particularly the use of plastic mulch, has well-documented benefits in agriculture. It contributes to soil moisture conservation, regulates soil temperature, suppresses weed growth, and enhances nutrient availability. Mulching plays a crucial role in moisture conservation. By covering the soil surface with a layer of mulch, water evaporation is significantly reduced. This, in turn, ensures a consistent and adequate water supply to the cucumber plants. Consistent moisture availability is essential for optimal plant growth, flowering, and fruit development. Mulching provides a micro-environment around the plant roots that helps mitigate water stress during critical stages, such as flowering and fruit set. The observed increase in plant height and a higher number of branches in mulched conditions align with previous studies by Ajibola & Amujoyegbe[27], and Akter et al.[28], where the application of plastic mulch resulted in a maximum vine length and the highest number of lateral branches. Furthermore, the significant increase in the number of leaves per plant with the application of mulch is consistent with findings by Ajibola & Amujoyegbe[27], and Akter et al.[28]. The improved growth and yield under mulching conditions can be attributed to these factors. The controlled soil environment created by mulching likely provided optimal conditions for root development and nutrient uptake, promoting overall plant growth. Additionally, the suppression of weed competition by mulch might have alleviated resource competition, allowing the cucumber plants to allocate more energy toward vertical growth. The agreement of the current results with the findings of Nair et al.[29] supports the efficacy of plastic mulch in increasing fruit production. This is further substantiated by Decoteau[30] and Jensen[31], who observed that mulching promotes earlier fruit production and contributes to greater overall yield. Mulching also contributes to temperature moderation in the soil. The layer of mulch acts as insulation, preventing extreme fluctuations in soil temperature. Cucumber plants are sensitive to temperature variations, and a stable, moderate temperature enhances their physiological processes. This moderation, particularly in regions with fluctuating climates, can positively influence flowering patterns, fruit development, and overall plant metabolism.

The choice and combination of fertilizers also played a crucial role in determining plant height. Farmyard manure serves as an organic source of nutrients, contributing to the soil's fertility. The slow release of nutrients from FYM ensures a steady and sustained supply of essential elements for plant growth. Organic matter in FYM improves soil structure, water retention, and microbial activity[6]. These factors create an environment conducive to nutrient uptake by the plant roots. FYM contains a range of macro and micronutrients that are essential for cucumber growth, including nitrogen, phosphorus, potassium, and various trace elements. The addition of NPK fertilizer complements the nutrient profile provided by FYM. NPK fertilizers are formulated to supply specific ratios of nitrogen (N), phosphorus (P), and potassium (K), addressing the key nutritional needs of plants. Nitrogen is crucial for vegetative growth, phosphorus for flowering and fruit development, and potassium for overall plant health. Cucumber vine length and the mean number of leaves per plant also showed a significant increase with the application of farmyard manure and fertilizer, as observed by Eifediyi & Remison[32]. Additionally, Murwira & Kirchmann[33] noted that combining manure and inorganic fertilizer enhances nutrient use efficiency, leading to higher

Table 9. Economic analysis of mulching and fertilizer combinations on cucumber growth and production.

Treatments	Total production costs (NRs./ha)	Yield (t/ha)	Average price of cucumber (NRs/kg)	Gross return (NRs.)	Net return (NRs.)	BCR
Mulching	154,500	25.93	20	518,600	364,100	2.35
Non-mulching	120,200	18.37	20	367,400	246,900	2.04
Control	125,500	14.53	20	290,600	165,100	1.31
FYM	138,303	23.71	20	474,200	335,897	2.42
NPK	142,500	22.39	20	447,800	305,300	2.14
FYM + NPK	155,303	27.97	20	559,400	404,097	2.6

yields. The combination of organic nutrients from FYM and readily available inorganic nutrients from NPK ensures a balanced and complete nutrient package for cucumber plants.

The synergy between mulching and fertilizers further contributed to the observed differences in plant growth and yield. Mulching might have created a favorable microenvironment that enhanced the efficiency of nutrient uptake from fertilizers. For instance, the controlled soil temperature and moisture levels provided by mulch can optimize nutrient solubility and microbial activity, facilitating nutrient absorption by plant roots. The elevated yield of 25.93 t/ha under mulching conditions, as presented in Table 8, finds support in the work of Karki et al.[34], who reported significantly higher cucumber yield under silver on black plastic mulch. Moreover, Eifediyi & Remison[32] concur with the results, emphasizing that the combined use of FYM and NPK contributes to maximizing cucumber yield. Overall, these findings highlight the practical significance of integrating mulching and fertilizers for optimizing cucumber cultivation outcomes. The interactive effects of mulching and fertilizers could have created an environment where the plants had access to both optimal growing conditions and essential nutrients, resulting in the maximum observed plant heights. The observed differences at different days after transplanting (DAT) highlight the dynamic nature of plant growth. Cucumber plants exhibit distinct growth phases, and the impact of treatments might vary at different developmental stages. The cumulative effect of mulching and fertilizers becomes more evident as the plants progress through various growth phases, leading to the observed differences in plant growth at 15, 30, and 45 DAT. The superior growth and yield under specific combinations of mulching and fertilizers result from a combination of improved soil conditions, sustained nutrient availability, and the synergistic effects of these practices. Understanding these intricate interactions is vital for optimizing agricultural practices and maximizing crop yields. The combination of organic FYM and chemical NPK fertilizer demonstrated superior performance in terms of cucumber growth and production. This synergistic approach not only resulted in better growth but also achieved higher production levels, all while maintaining a comparatively low cost of production. The economic analysis revealed that this combined treatment yielded the highest net return and BCR among all evaluated treatments. This indicates that the integration of organic and chemical inputs can be a judicious and economically rewarding strategy for cucumber cultivation, offering a balanced and sustainable approach to maximize both agronomic and economic outcomes[3,6].

Conclusions and recommendations

The study sheds light on the intricate dynamics of cucumber cultivation, emphasizing the pivotal role of mulching and fertilizer applications in influencing plant growth and yield. The observed variations in cucumber growth parameters and yield across different treatments underscore the specific influences of mulching and fertilization on various physiological and environmental factors crucial to plant development. Plastic mulching, known for its multifaceted benefits, significantly contributed to enhanced soil moisture conservation, regulated soil temperature, suppressed weed growth, and improved nutrient availability. These factors collectively fostered a favorable microenvironment for cucumber plants, leading to increases in plant height, number of branches, number of leaves, overall yield, and economics. Farmyard manure, serving as an organic nutrient source, played a crucial role in optimizing soil fertility. Its slow release of nutrients ensured a sustained supply, promoting steady plant growth. The addition of NPK fertilizer complemented the nutrient profile provided by FYM, addressing specific nutritional needs crucial for cucumber development. The combined application of these fertilizers created a balanced and complete nutrient package, contributing to the observed improvements in plant growth, yield, and benefit-cost ratio. The combined effects of mulching and fertilizers were observed to influence cucumber growth and yield. However, it's important to note that there was no significant interaction between mulching and fertilizer treatments for most measured variables, except for plant height. Therefore, it can be concluded that mulching and fertilizer treatments played distinct roles. Appreciating the individual impacts of mulching and fertilization are crucial for informed decision-making in agriculture, with potential benefits for farmers in terms of increased productivity, reduced production costs, and overall food security. Future research endeavors could delve deeper into the temporal dynamics of plant responses to these practices and explore additional factors influencing cucumber growth for a more comprehensive understanding of cultivation practices.

Author contributions

The authors confirm contribution to the paper as follows: study conception and design, data collection, analysis and interpretation of results, manuscript preparation: Acharya M, Ghimire S, Gautam N. All authors reviewed the results and approved the final version of the manuscript.

Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Acknowledgements

The authors are thankful to the Agriculture and Forestry University, Chitwan, Nepal, Prime Minister Agriculture Modernization Project, Nepal, and Assistant Professor Tulsi Parajuli for continuous support during the research work.

Conflict of interest

The authors declare that they have no conflict of interest.

Dates

Received 29 December 2023; Accepted 21 April 2024; Published online 13 May 2024

References

1. Mallick PK. 2022. Evaluating potential importance of cucumber (*Cucumis sativus* L. -Cucurbitaceae): a brief review. *International Journal of Applied Sciences and Biotechnology* 10:12–15
2. Guo Z, Qin Y, Lv J, Wang X, Dong H, et al. 2023. Luffa rootstock enhances salt tolerance and improves yield and quality of grafted

cucumber plants by reducing sodium transport to the shoot. *Environmental Pollution* 316:120521

3. Ghimire S, Dhami D, Shrestha A, Budhathoki J, Maharjan M, et al. 2023. Effectiveness of different combinations of urea and vermicompost on yield of bitter gourd (*Momordica charantia*). *Heliyon* 9:e18663
4. Kowalczyk K, Gajc-Wolska J, Mirgos M, Geszprych A, Kowalczyk W, et al. 2020. Mineral nutrients needs of cucumber and its yield in protected winter cultivation, with HPS and LED supplementary lighting. *Scientia Horticulturae* 265:109217
5. Li J, Yang X, Zhang M, Li D, Jiang Y, et al. 2023. Yield, quality, and water and fertilizer partial productivity of cucumber as influenced by the interaction of water, nitrogen, and magnesium. *Agronomy* 13:772
6. Ghimire S, Poudel Chhetri B, Shrestha J. 2023. Efficacy of different organic and inorganic nutrient sources on the growth and yield of bitter gourd (*Momordica charantia* L.). *Heliyon* 9:e22135
7. Larkin RP. 2020. Effects of selected soil amendments and mulch type on soil properties and productivity in organic vegetable production. *Agronomy* 10:795
8. Manzano V, García NL, Ramírez CR, D'Accorso N, Goyanes S. 2019. Mulch plastic systems: recent advances and applications. In *Polymers for Agri-Food Applications*, ed. Gutiérrez TJ. Cham: Springer International Publishing. pp. 265–90. https://doi.org/10.1007/978-3-030-19416-1_14.
9. Serrano-Ruiz H, Martin-Closas L, Pelacho AM. 2021. Biodegradable plastic mulches: impact on the agricultural biotic environment. *Science of The Total Environment* 750:141228
10. Haider FU, Hussan MU, Akhtar K, Cai L. 2022. Response of mulching and tillage practices on soil management. In *Mulching in Agroecosystems*, eds Akhtar K, Arif M, Riaz M, Wang H. Singapore: Springer, Singapore. pp. 71–87. https://doi.org/10.1007/978-981-19-6410-7_5.
11. Shah ST, Ullah I, Basit A, Sajid M, Arif M, et al. 2022. Mulching is a mechanism to reduce environmental stresses in plants. In *Mulching in Agroecosystems*, eds Akhtar K, Arif M, Riaz M, Wang H. Singapore: Springer, Singapore. pp. 353–76. https://doi.org/10.1007/978-981-19-6410-7_20.
12. Tang M, Liu R, Li H, Gao X, Wu P, et al. 2023. Optimizing soil moisture conservation and temperature regulation in rainfed jujube orchards of China's loess hilly areas using straw and branch mulching. *Agronomy* 13:2121
13. Thi Ba M. 1993. Effect of mulching method on growth and yield of cucumber. Nakhon Pathom, KaseSart University, Kamphaeng Saen campus, Thailand.
14. Lamont WJ Jr. 2017. Plastic mulches for the production of vegetable crops. In *A Guide to the Manufacture, Performance, and Potential of Plastics in Agriculture*, ed. Orzolek MD. UK: Elsevier. pp. 45–60. https://doi.org/10.1016/B978-0-08-102170-5.00003-8.
15. Pannacci E, Lattanzi B, Tei F. 2017. Non-chemical weed management strategies in minor crops: a review. *Crop Protection* 96:44–58
16. Bremner JM, Hauck RD. 2015. Advances in methodology for research on nitrogen transformations in soils. In *Nitrogen in Agricultural Soils*, ed. Stevenson FJ, Madison, WI, USA: American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America. 22: 467–502. https://doi.org/10.2134/agronmonogr22.c13.
17. Pratt PF. 2016. Potassium. In *Methods of Soil Analysis: Part 2 Chemical and Microbiological Properties, 9.2*, ed Norman AG. Madison, WI, USA: American Society of Agronomy, Inc. pp. 1022–30. https://doi.org/10.2134/agronmonogr9.2.c20.
18. Houba J, van Der Lee J, Novozamsky I, Walinga I. 1989. Soil and Plants Analysis. In *Part 5 Soil Analysis Procedures*. Wageningen University, Wageningen, The Netherlands.
19. Ghimire S, Thapa SJ, Khanal B. 2023. Evaluating soil nutrient status of mandarin orchards across varied altitudes in Gorkha, Nepal. *Fundamental and Applied Agriculture* 8:698–705
20. Mozaffari H, Moosavi AA, Baghernejad M, Cornelis W. 2024. Revisiting soil texture analysis: introducing a rapid single-reading hydrometer approach. *Measurement* 228:114330
21. Ministry of Agriculture & Livestock Development. 2021. *Statistical Information on Nepalese Agriculture 2076/77 (2019/20)*. Singhdurbar, Kathmandu, Nepal: Government of Nepal, Ministry of Agriculture and Livestock Development, Planning and Development Cooperation Coordination Division, Statistics and Analysis Section. https://moald.gov.np/wp-content/uploads/2022/04/STATISTICAL-INFORMATION-ON-NEPALESE-AGRICULTURE-2076-77-2019-20.pdf
22. Agriculture Information And Training Center. *Agriculture Diary 2078*. 2021. Hariharbhawan, Lalitpur, Nepal: Government of Nepal, Ministry of Agriculture and Livestock Development, Agriculture Information And Training Center. https://aitc.gov.np/uploads/documents/agriculture-diary-2078-for-web1619513804pdf-6696-107-1694581241.pdf
23. Gautam N, Ghimire S, Kafle S, Dawadi B. 2024. Efficacy of bio-fertilizers and chemical fertilizers on growth and yield of cowpea varieties. *Technology in Agronomy* 4:e007
24. Thapa R, Ghimire S, Bhattarai P, Acharya S, Poudel Chhetri B, et al. 2024. A comprehensive assessment of apple production in jumla district, Nepal: status, economics, marketing and challenges. *Turkish Journal of Agriculture - Food Science and Technology* 12:159–78
25. Ghimire S, Rauniyar UK. 2023. Economic analysis of acid lime production and marketing in Nepal: a benefit-cost perspective from Nawalpur East District. *Journal of Agriculture and Environment for International Development (JAEID)* 117:5–22
26. Yadav M, Ghimire S, Dhital M, Tharu RK. 2023. Response of carrot (*Daucus carota* Linn.) to different doses and sources of nitrogen in Sindhuli, Nepal. *Fundamental and Applied Agriculture* 8:717–29
27. Ajibola OV, Amujoyegbe BJ. 2019. Effect of seasons, mulching materials, and fruit quality on a cucumber (*Cucumis sativus* L.) variety. *Asian Journal of Agricultural and Horticultural Research* 3:1–11
28. Akter D, Islam MS, Ruhi RA, Joy MIH, Trina FA. 2020. Performance of mulching to the stimulation on the growth of cucumber (*Cucumis sativus*) production. *Bangladesh Journal of Multidisciplinary Scientific Research* 2:31–39
29. Nair A, Carpenter BH, Weieneth LK. 2013. Effect of plastic mulch and trellises on cucumber production in high tunnels. *Iowa State University Research and Demonstration Farms Progress Report* 2012:21–24
30. Decoteau D. 2008. The emergence and early development of colored reflective plastic mulch technology in agriculture. *Recent Advances in Agriculture* 2008:1–17
31. Jensen MH. 1990. Protected cultivation - a global review of plastics in agriculture. Proc. 11th International Congress the Use of Plastics in Agriculture. New Delhi, India, 1990. pp. 3–10. Rotterdam, Netherlands: A. A. Balkema.
32. Eifediyi EK, Remison SU. 2010. Growth and yield of cucumber (*Cucumis sativus* L.) as influenced by farmyard manure and inorganic fertilizer. *Journal of Plant Breeding and Crop Science* 2:216–20
33. Murwira H, Kirchmann H. 1993. Carbon and nitrogen mineralization of cattle manures, subjected to different treatments, in Zimbabwean and Swedish soils. *Soil Organic Matter Dynamics and the Sustainability of Tropical Agriculture: Proceedings of An International Symposium, Leuven, Belgium*. John Wiley & Sons Ltd. pp. 189–98.
34. Karki A, Sapkota B, Bist P, Bista K, Dutta JP, et al. 2020. Mulching materials affect growth and yield characters of cucumber (*Cucumis sativus* cv. Malini) under drip irrigation condition in Chitwan, Nepal. *Journal of Agriculture and Forestry University* 4:153–59