IMPACT OF MULCHING AND ITS RESIDUES ON GROWTH, YIELD AND ECONOMIC PERFORMANCE OF SELECTED SUMMER AND WINTER VEGETABLES

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DEDICATED TO

ALL THE FARMERS

OF THE WORLD

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ABSTRACT

Two different field experiments were carried out to investigate the impact of mulching and its residues on growth, yield and economic performance of selected summer and winter vegetables at the Germplasm Centre of Agrotechnology Discipline, Khulna University, Khulna during June 2015 to May 2016. Experiments were conducted on three summer vegetables viz. Gima Kalmi, Okra and Indian Spinach in combination with four different mulching viz. control (no mulch), Rice straw, Water hyacinth, Duck weed and three winter vegetables viz. Tomato, Brinjal and Knolkhol in combination with residues of those mulching. Both experiments were laid out in a Randomized Complete Block Design (RCBD). Data were collected on parameters like plant height, number of leaves plant^{-1}, length of largest leaves, width of largest leaves, number of branch plant^{-1}, diameter of plant and yield. Different mulching and mulching residue had significant influence on yield and yield contributing characters of different vegetable. In experiment-1 maximum yield of Gima kalmi (9.70 ton/ha), Okra (7.20 ton/ha) and Indian spinach (15.30 ton/ha) were obtained from Rice straw, Duck weed, Water hyacinth mulching treatment respectively. Again, in experiment-2 maximum yield of Tomato (48.32 ton/ha), Brinjal (22.1 ton/ha) and Knolkhol (19.36 ton/ha) were obtained from Water hyacinth residue treatment. In experiment-1 most economically beneficial vegetable-mulching combination was Gima kalmi with Rice straw mulching. In case of experiment-2 most economically beneficial vegetable-mulching residue combination was Tomato with Water hyacinth residue.

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ABBREVIATIONS

cm	Centimeter
kg	Kilogram
fig	Figure
viz	Namely
et al.	and others
BCR	Benefit cost ratio
CV	Coefficient of variation
DAT	Days after transplanting
DAS	Days after sowing
DMRT	Duncan's multiple range test
FAO	Food and Agriculture Organization of the United Nations
t/ha	Ton per hectare
LSD	Least significance difference
LS	Level of significance
TSP	Triple super phosphate
MoP	Muriate of potash
RH	Relative humidity
SRDI	Soil Resources Development Institute
AEZ	Agro ecological zone
RS	Rice straw
DW	Duck weed
WH	Water hyacinth

CHAPTER: I

INTRODUCTION

Agriculture is one of the most dominant sector of Bangladesh economy and largest employment sector in Bangladesh. As of 2016, it employs 47% of the total labor force and comprises 16% of the country's GDP (The World Factbook, 2016). Vegetable production, being a sub-sector, plays an important role for the economy of Bangladesh. Nearly 100 different types of vegetables comprising both of local and foreign origins are grown in Bangladesh. The country earns a lot of foreign currency (182m USD in 2012-13) by exporting vegetables. (Hortex Foundation Bangladesh, 2012).

Bangladesh is a heavily populated country. People of Bangladesh are suffering from malnutrition problem. Per-capita consumption of vegetable in Bangladesh is perhaps the lowest among the countries of South Asia and South-East Asia. Vegetable sub-sector can play important role to solve these problems. (Hortex Foundation Bangladesh, 2012).

According to USDA (2014), vegetables compared to other food items provide nutrition at low cost. It can be produced even small amount of land and also in homestead area. It can be grown within a short time period and more than one crop can be grown within a crop season. There are a large number of vegetables having different varieties, which can be grown throughout the year. Vegetables are generally labor intensive crops and thus offer a considerable promise for generating increased rural employment opportunities.

Vegetable production in Bangladesh is still not up to our full potential. We are not being able to exploit our full potential due to a number of reasons. Scarcity of irrigation water is one of them. Often, in late Robi season we face a scarcity of irrigation water. Another reason is low organic matter content in our soil. About 3.6m ha of land have less than 1.7% organic matter in soil in our country (SRDI, 2016). Moreover soil erosion due to water and air makes loss to the upper fertile horizon of soil. Weed infestation is another

hindrance on the way to better production. Plants fail to uptake necessary nutrient elements competing with weeds. Salinity is another major problem that reduces overall vegetable production. The southern regions of our country are affected with salinity which reduces growth and yield of vegetable plants (SRDI, 2016).

To resolve the above mentioned problems, the researchers are striving to find better solutions. In this regard mulch may be considered as one of the options favored by the researchers. Mulch is a layer of material (synthetic or natural) applied to the soil surface mainly in order to conserve moisture, to improve fertility, to reduce weed growth. It can be temporary or permanent in nature.

Mulch materials create a barrier on the soil surface to inhibit the transfer of heat and vapor (Rosenberge *et al.*, 1983). Plastic paper (mainly transparent and black) and natural materials (water hyacinth, rice straw, ash, saw dust, etc.) are used as mulches. Mulching protects the loss of soil moisture by soil evaporation induced by wind and reduces the irrigation requirements (Roy *et al.,* 1990). Mulches also help in better utilization of all the nutrients in the soil meeting up the need of irrigation and thus increase crop yield. Mulching stimulates microbial activity in soil and thus improves agrophysical properties (Lee and Yoon, 1975) in soil. Assi and Rayyan (2007) reported that plant height was increased in mulches than bare land. Any mulch increases number of leaves per plant and yield of potato, garlic as well as soybean compare than non- mulch treatment (Talukder, 2002; Manna 2000).

Mulch can be applied to increase the effectiveness of watering. Since the mulch reduces the loss of fertilizers by eliminating downward movement during heavy rain, it is possible to reduce near about 25% amount of fertilizer (Diane, 2000).

Among mulch's greatest attributes is its ability to help control weeds. Mulch also helps conserve soil moisture by 50% or more by covering the soil to slow down evaporation (Holmer, 1998). Nutrients do not leach so readily under mulches because less rainwater penetrates. Vegetables remain cleaner in mulched gardens because they have less contact with the soil. Finally, organic mulches can keep soil cool.

Soils will remain cool longer in the spring under organic mulches, because the sun does not strike the soil. Most of organic mulches will compact and start to decompose. They can be tilled under easily, adding valuable organic matter to the soil. Some gardeners prefer to maintain permanent mulch, adding organic materials as it becomes available. In the spring, they simply pull back the mulch in spots for transplants or in rows for direct-seeded vegetables. This method is a good way to build a rich garden soil (Ahmad *et al.*, 1999).

Use of mulching is not a new practice in Bangladesh. But still it is not popular or well adopted across every part of the country. Information stated above concludes that use of mulching could be a key to better vegetable production, a solution to our malnutrition problem and a tool of maximizing net profit. There are many types of mulching with different physical and chemical properties having different level of impact on growth and yield of vegetables. So, identifying suitable mulching for achieving maximum vegetable production is necessary.

Considering above circumstances, the present study was undertaken with the following objectives:

- To indentify the suitable mulching materials for better growth and yield of different summer vegetables.
- To identify mulching materials that has maximum residual impact on growth and yield of winter vegetable.
- To identify most economically profitable summer and winter vegetable in respect of mulching operations and their residual effects.

CHAPTER: II

REVIEW OF LITERATURE

Mulching has a very positive impact on growth and yield of any crop. It increases plant growth and production of yield by suppressing weed growth, manipulating plant microclimate, supplying organic matter after decomposition, reducing soil erosion, holding soil moisture and in many other ways. So, use mulching could bring an increase to the vegetable production of our country. Studies have been carried out to find out the impact of mulchings on growth and yield of vegetables. Some of the relevant studies which have been performed on mulching are reviewed bellow:

Ogundare (2014) performed an experiment on Response of Tomato Variety (Roma VF) yield to different mulch materials and staking and recommended that black Polythene should be used as mulch materials for tomato production.

Dalorima *et al.* (2014) reported from an experiment on effects of different mulching materials on the growth performance of Okra. The results show that growth parameter like plant height, weed count and flower bud count has no significant difference between the treatments but all treatment has some superiority to the control.

Rahman *et al.* (2013) conducted a field experiment to evaluate the influence of mulching (M) on the growth and yield of onion (*Allium cepa*) cv. Taherpuri. Treatments of the experiment were three types of mulching such as no mulch or control (M_0), rice straw (Ms) and water hyacinth (Mw). The results indicated that growth parameters were increased significantly with the application of mulching (M). Mulching with water hyacinth numerically gave the highest yield (10.46 t /ha) than the mulching with rice straw (9.78 t /ha).

Mochiah *et al.* (2012) conducted an experiment to study the effect of different mulching materials on agronomic characteristics, pests and their subsequent effect on the natural enemies of the pests of pepper (*Capsicum annuum*). The results indicated that straw mulch enhanced plant height and increased fruit number and percentage yield whilst live-mulch of cowpea and plastic mulch reduced plant height, fruit number and percentage yield.

Higher total okra fruit yield was observed in plants on grass mulch than those on the control (Norman *et al.*, 2011). The highest total fruit yield of hot pepper was produced by sawdust mulch than the control (Norman *et al.*, 2011). Bare soil plots resulted in lowest yield of tomato but this was not significantly different from yields obtained from mulched plots (Osei-Bonsu and Asibuo, 2013).

Masanta and Mallik (2009) conducted an experiment on the effect of mulch and irrigation on yield and water use efficiency of wheat. The results reveal that application of surface mulch enhance the productivity significantly by improving soil moisture status over no mulch treatment and use of white polythene mulch found to be better compare to black polythene as well as straw and leaf mulch. Water expense efficiency was also maximum under white polythene mulch. Application of mulch not only improves the productivity but also reduce the number of irrigations. However, due to the high price of synthetic mulch the economic gain was maximum under locality available mulch material i.e. straw and leaf mulch.

Kayum *et al.* (2008) performed an experiment on Effects of Indigenous Mulches on Growth and Yield of Tomato. The experiment revealed that water hyacinth and straw mulches have potentiality to increase the yield of tomato.

Venkanna, (2008) carried out an experiment to determine the growth and yield response of okra to different organic manures, branch number was influenced significantly by mulching.

Dauda (2011), reported that no significant effect on the number of branches per pepper plant by Grass mulch compared to the control. Dry grass mulch produced higher number of branches in okra than control (Norman *et al.*, 2011).

Assi and Rayyan (2007) conducted an experiment to know the effect of mulches on nutrient availability in onion and reported that mulches increased nutrient availability than control. Similar result was also reported by Chhangani (2000) and Gitaitis *et al.* (2004) in sweet onion.

Pinjari (2007) conducted field experiments during 2005-06 and 2006-07 to find out the effect of polythene mulch on sweet corn and reported that plant height, dry matter accumulation per plant and in the different plant parts i.e. leaves, stem, grains, cob axis, cob sheath of sweet corn were significantly superior under polythene mulch over no mulch at all the crop growth stages during both the years and in the mean of two years.

Awodoyin (2007) conducted an experiment on the effects of three mulch types on the growth and yield of tomato and reported that Mulches are effective in weed control and conservation of soil moisture, and the plant-based mulches are most effective in reducing soil temperature.

Significantly higher fresh yield of lettuce was recorded from mulch treated plot than that from control (Moniruzzaman, 2006).

Gosavi (2006) after conducting the field trial at Aspee foundation, Thane on sweet corn reported that the significantly greater plant height and numerically increased number of

functional leaves per plant and dry matter at 30 and 60 DAS of the sweet corn grown under polythene mulches than no mulch treatment and paddy straw mulch.

Mulches have a profound influence on plant growth as well as branch production in field crops. Halim (2006) studied the effect of polythene mulches (transparent, blue and black color) on chili and reported that branch production was higher in polythene mulched plots than control with being the highest in black polythene mulch.

Hashem (2005) carried out an experiment on effects of manuring and mulching on growth and yield of broccoli in BAU Mymensing and observed that the maximum average yield (17.6 t/ha) was obtained from organic and inorganic fertilizers with black polythene mulch.

Kashyap *et al.* (2005) conducted a field experiment to study the growth, yield and water use efficiency of broccoli cv. KTS-1 with or without black plastic mulch. The highest broccoli yield of 25.14 t/ha was found under drip irrigation at 120% EPR with black plastic mulch, while the lowest yield of 9.22 t/ha was recorded in the furrow-irrigated plants.

Kudtarkar (2005) after conducting a field trial at Thane on groundnut reported that total nitrogen, phosphorus and potassium was significantly higher under polythene mulch than no mulch treatment.

Azam (2005) reported the highest bulb yield was recorded from black polythene mulch (11.83 t/ha) followed by transparent polythene mulch (11.63 t/ha), rice husk mulch (10.84 t/ha) and rice straw mulch (8.87 t/ha) and the lowest was recorded in unmulched plot (6.67 t ha"). Similar result was also reported by Ali (2004) in broccoli.

The effect of plastic, straw and sawdust mulches on yield and yield component of garlic was evaluated by Jamil *et al.* (2005) and the highest bulb yield in plastic mulch followed by straw mulch and the lowest with sawdust.

Diaz-Perez *et al.*, (2004) reported that plants under mulch produced longer root than bare land in onion. The effect of mulching (Black polythene, straw and water hyacinth) on the growth and yield of garlic were studied by Islam *et al.* (2007) and they found that black polythene treated plants produced the longest root followed by water hyacinth.

Miura and Watanabe (2004) conducted a field experiment at National Agricultural Research Centre of Tohoku region, Japan on sweet corn and reported that growth rate and effective weed control were significantly higher under white polythene mulch as compared to red polythene mulch and living leguminous mulch treatments.

Bhatt *et al.* (2004) conducted a field experiment at Punjab Agriculture University, Ludhiana on maize and reported that dry matter production with paddy straw mulch was higher by 138% than the dry matter production from bare plots.

Kwabiah (2004) reported from a field experiment conducted on sweet corn that there was increase in soil and air temperature (2θ °C) so there was early germination by 3-5 days and correspondingly delayed silking by 8-17 days and maturity by 7-13 day and also higher plant growth under transparent plastic mulch over no mulch treatment.

Correa *et al.* (2003) conducted an experiment in Brazil to evaluate the effect of soil mulching on garlic and reported that soil mulch resulted in higher growth and yield than control (no mulching). Similar result was also reported by Gunadi (1998) in potato.

An experiment was conducted by Asaduzzaman (2003) to investigate the effect of different indigenous mulches (water hyacinth, straw, leaves of am-ada and banana) on growth and yield of tomato and reported that plant growth and development was higher in water hyacinth mulch compared to other mulches due to water conservation capacity and nutrient availability for the mulching.

Stem diameter Stem diameter represents the robustness of a plant. Nagalakshmi *et al.* (2002) studied the effect of plastic mulch on growth and yield of chilli and reported that stem diameter was greater in plastic mulch plant than control.

Saha (2001) conducted an experiment at the Field Laboratory of the Department of Crop Botany, BAU, Mymensingh in order to the study of the effect of synthetic mulch on tomato. Plant height, branching, flowering, fruiting, root length, fruit weight, fresh and dry weight of roots, stem leaves and weed-biomass were significantly influenced by different synthetic mulches over the control.

Mulches have a significant effect on plant height as reported by most of the researchers. Chakraborty (2000) studied the effect of paddy straw mulch on growth; yield and water use efficiency of chilli growing in a saline ecosystem and reported that plant height increased by 37.1% in paddy straw than control. Similar results were also reported by many workers (Zubair, 2006; Liasu and Achakzai, 2007).

Dey (2000) conducted an experiment at the Horticultural Farm, Bangladesh Agricultural University, Mymensingh in order to study the effect of nitrogen and mulch on the growth and yield of carrot. Mulching treatments exhibited a significant influence on plant height, number of leaves, weight of roots, and gross yield of roots and marketable yield of roots.

Patel *et al.* (1999) used black, green and yellow plastic mulch on okra and reported that black polythene mulch produced the highest fruit yield. Similar result was also reported by Singh *et al.* (2006) in brinjal.

Mohapatra *et al.* (1998) found that plastic mulching with transparent polythene film mulch or linear low-density polythene also increased the soil moisture content.

An experiment was conducted by Monks *et al.* (1997) on tomato and mulches (shredded newspaper, chopped newspaper, wheat straw, black plastic and plastic landscape fabric). They observed that chopped newspaper provided higher tomato yield than shredded newspaper applied at the same rates.

Generally, the soil moisture under mulched plots was significantly higher than that of the control as were reported by most of the workers (Ravinder *et al.*, 1997; Mohapatra *et al.*, 1998; Shelly, 2002; Rahman, 2004; Halim, 2006).

Sandal and Acharya (1997) showed that conservation tillage like mulching is very effective to moderate or alter the soil moisture regimes. Mulches (viz. maize stubble, rice straw, wheat straw, saw dust, crop residues) increased or conserved the soil moisture content.

Plant height, leaf number, bulb diameter and bulb yield of onion was significantly higher for mulch than unmulched plant as was noted by Mia (1996). Similar result was also reported by Hossain (1996) in garlic.

Saifullah *et al.* (1996) carried out an experiment with four different mulches viz. water hyacinth, black polythene, straw and saw dust on growth and yield of cabbage. Yield and most of the yield contributing characters like plant height, number of loose leaves plant, diameter and thickness of head, weight of loose leaves, stem, root, head, whole plant and total dry matter were significantly increased by irrigation and mulch treatment. The highest marketable yield was obtained by irrigation treatment followed by black polythene, water hyacinth, sawdust and straw (24.64 t/ha) and the lowest (12.68 t/ha) by control treatment.

Fortnum *et al.* (1995) conducted an experiment using different colored polythene mulches and reported that soil moisture was greater in black and red polythene than white mulch.

Baten *et al.* (1995) noted that the effectiveness of water hyacinth, rice straw and dried grass mulches increases the number of leaves and suppresses weed growth in garlic compared with the control. Mulches had a significant effect on plant height of maize (Quayyum and Ahmed, 1993).

Lamont (1993) opined that mulching help in checking evaporation and thus soil can retain sufficient amount of moisture which help rapid growth and development of field crops.

While working with tomato plant grown on polythene mulch in New York State Wien *et al.* (1993) reported that the plants had more branches and higher mineral nutrient uptake and yielded more than the plants not mulched. They also found that mulching increased branching hastened flowering on basal branches and increased the concentration of major nutrients in the above ground parts.

Suh *et al.* (1991) used transparent and black polythene mulch to onion crop and reported that number of leave of plant was greater in both transparent and black polythenes than control. Similar result was also reported by Abu- Awwad (1999) in onion.

An experiment was conducted by Gonzalez and Vives (1990) with mulches (Black polythene, blue polythene, rice husk and saw dust) on tomato in Costa Rica and found that black, blue and red polythene mulches increased chlorophyll than rice husk or sawdust mulches.

Roy *et al.* (1990) by using water hyacinth, straw and sawdust as mulch on potato opined that mulches increased leaf area index (LAI) and crop growth rate (CGR).

Duhr and Dubas (1990) reported that mulched plants enhanced stem diameter of maize. Similar result was also reported by Shelly (2002) in maize, by Zubair (2006) in soybean and by Halim (2006) in chilli.

Mulching can play important role to protect surface soil from erosion and loss of soil moisture. Kumar and Sadanandan (1988) stated that mulching was beneficial to protect the surface soil from erosion, weed growth and loss of nutrients and moisture.

Al-Jebori, *et al.* (1987) studied on the effectiveness of black polythene, silver polythene, newspaper, straw and no mulch or control, mulching treatments under two nitrogen fertilizer sources (Ammonium sulphate and Urea) at 100 kg N/ha on tomato plants (Super Marinando cultivar) resulted that black and silver polythene mulches significantly increased early production and total yield.

Similarly, Perry and Sanders (1986) reported that black polythene mulch increased early and total yield of large and marketable fruits of tomato. Both polythene and straw mulches appeared to have considerable increasing effect on plant height (Gunadi and Suwanti, 1988).

Famoso and Bautista (1983) conducted an experiment on tomato production, mulching with sugarcane truss and straw. They stated that mulching with rice straw increased the number of flowers and the chlorophyll content of the leaves in tomato as a result enhanced the yield of tomato.

As mentioned by Asandhi and Suryadi (1982), rice straw mulching markedly increased potato plant height and leaf area, but had no effect on the number of stems/plant and DM production.

Rashid *et al.* (1981) conducted a trial at Joydebpur, Dhaka on potato, cultivated with or without ridges; without mulching or mulching with water hyacinth, rice straw, and rice spikelets (Chitta). Tuber yield was the highest (17.6 t/ha) when the plants were ridged and mulched with water hyacinth.

Chen and Katan (1980) observed that nitrate, ammonium, potassium, calcium, magnesium, chlorine, sodium and extractable phosphorus increased by polythene mulch.

From above review of literature it has been revealed that the work on the effect of different mulching on the growth and performance of different vegetable has been done by a number of researchers. But work on different vegetable with different mulching to find out most suitable and profitable combination for each vegetable is rarely done. On the other hand, works on the impact of mulching residue is meager in Bangladesh. So, the present study was undertaken to find out the most suitable, beneficial mulching and vegetable combination and to find out mulching having most residual impact.

CHAPTER: III

MATERIALS AND METHODS

Details of different materials and methodologies followed during the whole experimental period have been presented in this chapter.

3.1 Experimental site

The experiment was carried out at the field in the Germplasm centre of the Agrotechnology Discipline , Khulna University during June 2015 to May 2016 which is located at latitude 22°48′35″ N, longitude 89°33′51″ E and altitude 8 m above sea level.

3.2 Climate and weather of the site

The experimental area was under the sub-tropical climate which was characterized by heavy rainfall, high humidity, high temperature and relatively long day during the Kharif season (April to September) and scanty rainfall, associated with moderately low temperature and short day period during the Rabi season (October to March). Details of the meteorological data for the period under study have been shown in Appendix III.

3.3 Characteristics of soil

The experimental field was medium high land of clay-loam with gray colored having pH 8.0.

3.4 Treatments of the experiment

Experiment-1 consisted of three type of summer vegetable and four type of mulching.

Three types of vegetables: C_1 = Gima Kalmi
C_2 = Okra
C_3 = Indian Spinach.

Treatment - 4 mulches: M_0= Control (No Mulch)

M_1 = Rice Straw

M_2 = Water Hyacinth

M_3 = Duck weed

Experiment-2 consisted of three types of winter vegetable crop and four type of mulching residues.

Three types of vegetables: C_1 = Tomato

C_2 = Knolkhol

C_3 = Brinjal

Treatment – Residue of 4 mulches: MR_0 = Control (No Mulch residue)

MR_1 = Rice Straw residue

MR_2 = Water Hyacinth residue

MR_3 = Duck weed residue

3.5 Planting Materials

Seeds of Gima Kalmi and Okra were collected from local Gollamari More market and seedling of Indian spinach, tomato, knolkhol and brinjal were collected from local farmer. Local varieties were used for all vegetables.

3.6 Design of the experiment

In the experiment-1 there were 12 treatment combinations which were C_1M_0, C_1M_1, C_1M_2, C_1M_3, C_2M_0, C_2M_1, C_2M_2, C_2M_3, C_3M_0, C_3M_1, C_3M_2, and C_3M_3.

In the experiment-2 there were 12 treatment combinations which were C_1MR_0, C_1MR_1, C_1MR_2, C_1MR_3, C_2MR_0, C_2MR_1, C_2MR_2, C_2MR_3, C_3MR_0, C_3MR_1, C_3MR_2, and C_3MR_3.

Both experiments were laid out following Randomized Complete Block Design (RCBD) with five replications. The size of the each unit plot was 2.0m x 1.5m. The distance maintained between two blocks was 75cm and two plots were 50 cm. In experiment-2, Tomato was planted on the plots of previous crop Gima Kalmi, Knolkhol was planted on the plots of previous crop Okra, Brinjal was planted on the plots of previous crop Indian Spinach.

3.7 Land preparation

Both of the time field soil was prepared for planting with spade. As it was a medium high land, deep furrows were made between plots to provide good water drainage and that soil was placed over adjacent plots. Dry roots, grasses, stubbles and other particulate materials were removed from the soil. Soil was exposed to the sun for one week. Then plots were made according to the design of each experiment.

3.8 Soil test

Initial soil nutrient status was examined by taking soil samples and checking it at SRDI laboratory, Daulatpur, Khulna. The samples were taken randomly from the plots at 0-15 cm depth from surface before each experiment. The nutrient status has been presented in Appendix IV.

3.9 Application of fertilizer

In case of experiment-1, required amount of manure and fertilizer were applied to the soil as per recommended rate. The entire amount of cowdung as per recommendation was applied at the time of initial land preparation. 50% of the whole amount of TSP, MoP and 25% Urea were applied after plot layout was done. Rest 25% Urea was applied at 15 days

after sowing. The applied fertilizers were mixed properly with the soil of each plot using a spade.

The amount of manures and fertilizers are given in the following table.

Table 1: The doses of manure and fertilizers used in experiment-1.

Manure/ Fertilizer type	Gima Kalmi		Okra		Indian Spinach	
	Per ha	Per plot ($3m^2$)	Per ha	Per plot ($3m^2$)	Per ha	Per plot ($3m^2$)
Cowdung	5000 kg	1.5 kg	7500 kg	2.25 kg	6000kg	1.8 kg
Urea	125 kg	37.5 g	150 kg	45 g	240 kg	72 g
TSP	75 kg	22.5 g	100 kg	30 g	150 kg	45 g
MoP	100 kg	30 g	160 kg	48 g	150 kg	45 g

In case of experiment-2, no chemical or organic fertilizer/manures were applied.

3.10 Application of mulch materials

In case of experiment-1, four types of mulches, viz. No Mulch (Control), Rice Straw, Water Hyacinth and Duck Weed were placed on the respective plots after seven days of land preparation. Water hyacinth, duck weed and rice straw were dried in the sun for seven days before placing over the plot. The crop was mainly raised under rain-fed condition. Small holes were made on the placed mulching cover by hand or small tool to facilitate seed germination and sowing of seedling.

Again, in experiment-2, Soil of the plots was ploughed with spade to give a minimum tillage for planting, makes minimum disturbance to the soil structure and mix mulch residue to the soil. Dry roots, grasses, stubbles and other particulate materials were removed from the soil. Soil was exposed to the sun for one week.

3.11 Sowing of seed and transplantation of seedlings

Gima Kalmi and okra seeds were soaked in water for 24 hrs to ensure better germination. Gima Kalmi was sown in three rows per plot. Row to row distance was 50cm. Indian Spinach, Tomato, Knolkhol and Brinjal seedlings were transplanted at 12 plants per plot with 3 rows. Row to row and plant to plant distance was 50cm for both plants. For transplantation, healthy seedlings of equal size were collected and used. For Okra two seeds were sown per hole.

3.12 Intercultural operations

After sowing/transplanting of the seedlings, different intercultural operations were accomplished for better growth and development of the plants.

3.13 Gap filling

Gap filling was done as necessary with healthy seedlings.

3.14 Weeding

Hand weeding was done as and when needed.

3.15 Irrigation

For both of the experiments, Irrigation was only given in the 1st week on seed sowing and seedling transplanting. Then those vegetables were grown under rainfed condition.

3.16 Staking

Bamboo sticks were used for staking purpose in Okra and Tomato plant when plants achieved a good height.

3.17 Insects and disease control

No chemical insecticide or pesticides were applied.

3.18 Harvesting

The crop was harvested at the marketable maturity of each vegetable.

DATA COLLECTION

Three most healthy plants were selected from each unit plot and the mean value for each parameter was calculated to collect the experimental data. Following parameters were recorded during the course of experiment.

4.1 Plant height

Plant height was recorded in centimeter at different Days after sowing (DAS) / Days after transplanting (DAT). Measurements were done from the ground level to the tip of the longest stem.

4.2 Number of leaves per plant

Number of leaves per plant was recorded at different DAS/DAT for both summer and winter vegetables.

4.3 Length of largest leaf

Length of largest leaf was recorded in centimeter with a meter scale as the horizontal distance covered by leaf at 75 DAS/DAT for summer vegetables and at 60 DAT for winter vegetables.

4.4 Width of largest leaf

Width of largest leaf was recorded in centimeter with a meter scale at 75 DAS/DAT for summer vegetables and at 60 DAT for winter vegetables.

4.5 Diameter of the plant

Diameter of the plant was recorded in centimeter with a meter scale on 75 DAS/DAT. Measurements were done at the place whereas visually the stem looked larger.

4.6 Number of branch per plant

Number of branch per plant was recorded on 75 DAS/DAT for summer vegetables and at 60 DAT for winter vegetables.

4.7 Yield per plot

Yield per Plot was calculated by totaling all yield together harvested each time. Yield (ton) per hectare was also calculated.

Statistical analysis

The collected data on various parameters were statistically analyzed using MSTAT-C computer package program. The mean for all the treatments were calculated and analyzed. Analysis of variance for all the characters was performed by F-variance test. The significance of difference between the pairs of treatment means was calculated by the Duncans Multiple Range Test (DMRT) at 5% level of probability.

CHAPTER: IV

RESULTS AND DISCUSSION

This chapter comprises the presentation and discussion of the results from the experiments conducted to determine the impact of mulches and mulch residues on growth and yield of different summer and winter vegetables. Data have been presented graphical and tabular form and analyses of variance in respect of all the parameters have been shown in appendices (I and II). The results of all parameters have been given under the following heading.

4.1 Plant height

Plant height is one of the important parameter which is positively correlated with yield for most of the plants plant height was recorded at different days after sowing/transplantation. For better understanding, the trends of plant height at different DAS/DAT have been presented graphically (Fig. 1, 2, 3.)

From the growth pattern (Fig. 1) we can see plant height of Gima Kalmi was influenced by different mulching. From the beginning plants treated with rice straw mulching grew more than others. At some point the differences was not significant. The reason could be the incomplete decomposition of mulching materials to release organic matter. But other effects were almost similar (e.g. manipulation of temperature, prevention of soil erosion and fertilizers wash off).

A significant variation in plant height at 75 DAS was observed from Gima Kalmi plants due to the influence of mulch materials in M_1 (37.00cm), M_3 (36.20cm) and M_2 (36.60cm) when compared to control (32.60cm) (Fig.1). Plants grown in M_1 (37.00cm) gave the highest plants height followed by M_3 (36.20cm) and M_2 (35.60cm). But plant heights among those three types of much (M_1, M_3 and M_2) treatment didn't vary significantly. The lowest plant height was observed from the control (32.60cm).

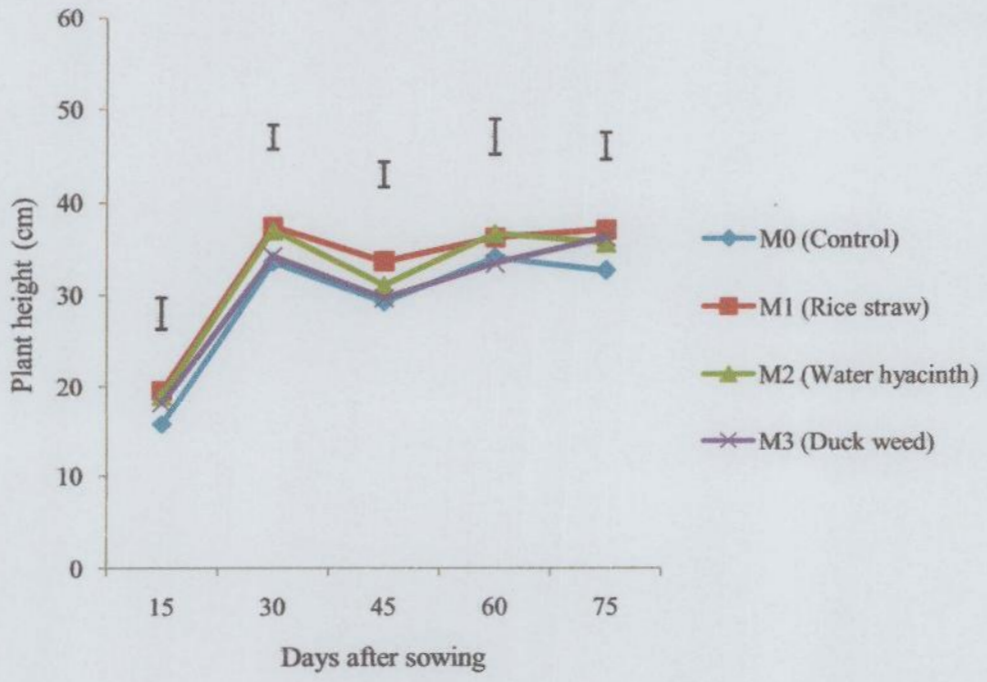

Fig. 1: Effect of different mulching on plant height of Gima kalmi at different DAS (Vertical bars represents $LSD_{0.05}$)

Okra plant height at 75 DAT resulted a significant variation due to the influence of mulch materials in M_1 (120.8cm) and M_3 (104.8cm) when compared to Control (85.00cm). M_1 (120.8cm) gave the highest plant height (Fig: 2) followed by M_3 (104.8cm) and then the Control (85.00cm). The effect of M_2 (60.40cm) and Control (85.00cm) was statistically identical. Somehow M_2 (60.40cm) provided the lowest plant height. This could be due to more lateral growth.

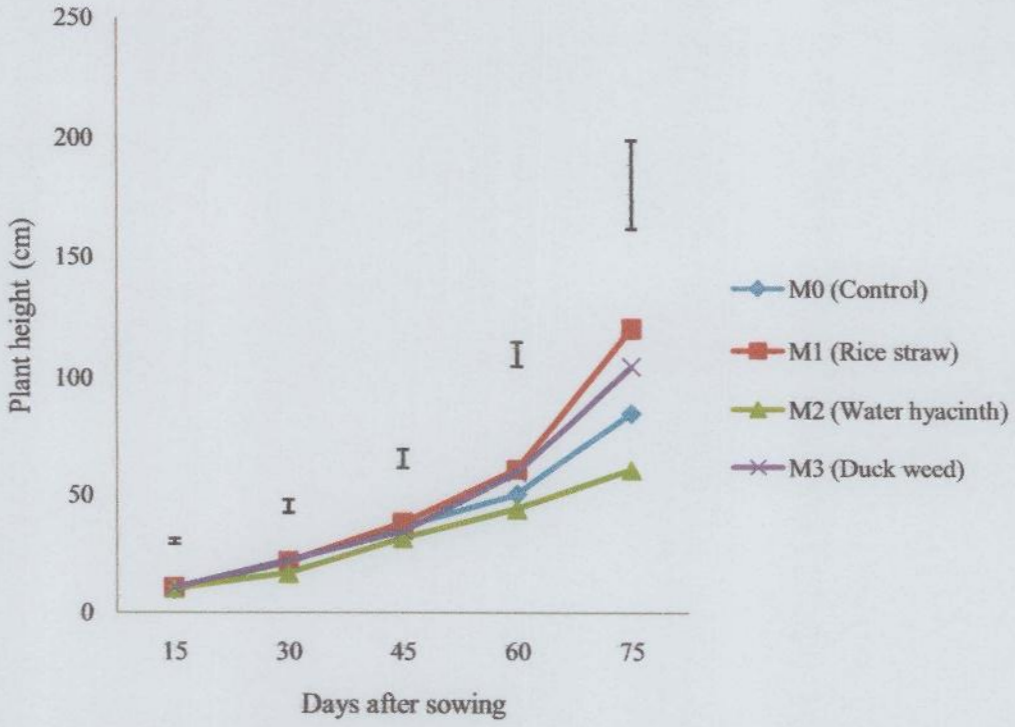

Fig. 2: Effect of different mulchings on plant height of Okra at different DAS (Vertical bars represents $LSD_{0.05}$)

Effect of mulching on Plant height of Indian Spinach was significantly different for all mulches when compared to control at 15 DAT. However, after 1st harvest only water hyacinth resulted a noticeable difference compared to others. Plant heights were significant at 75 DAT in M_2 (68.60cm) and M_3 (58.40cm) compared to Control (49.80cm) where M_1 (54.20cm) was identical to Control (Fig: 3). The highest plan height was observed from M_2 (68.60cm) followed by M_3 (58.40cm) and then M_1 (54.20cm) whereas the lowest was found in Control (49.80cm). Mulching had a positive impact on plant height when compared to no mulch. So, mulching seems to have a positive impact on plant height of Indian Spinach plant.

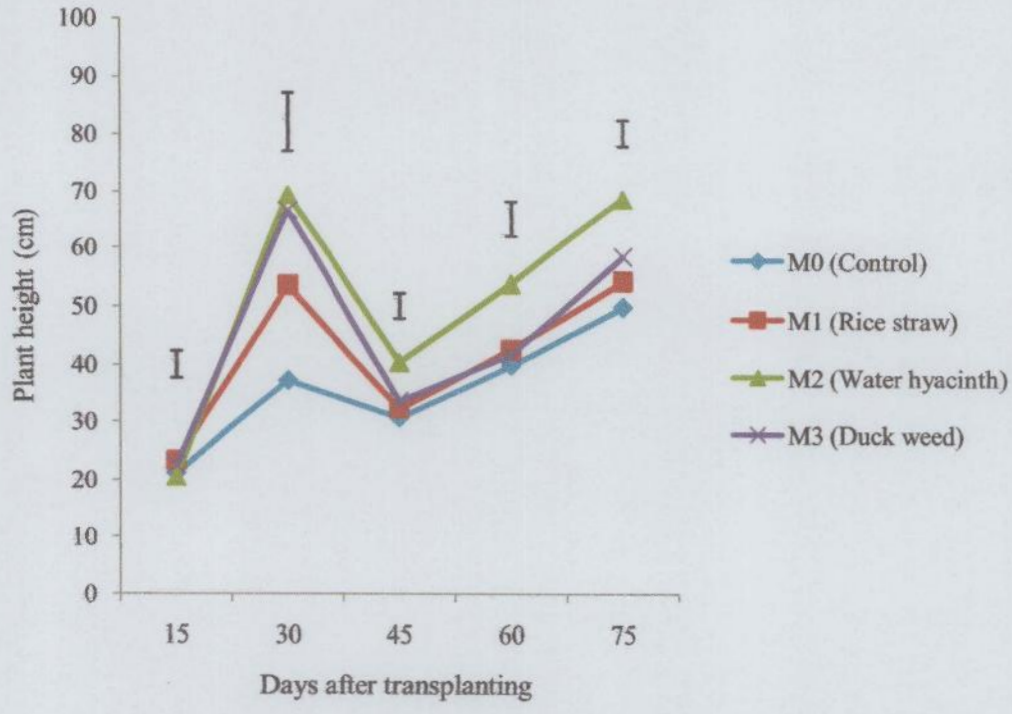

Fig. 3: Effect of different mulchings on plant height of Indian spinach at different DAT. (Vertical bars represents $LSD_{0.05}$)

Plant height of Tomato didn't vary significantly among mulch treatments (M_1, M_2 and M_3) for first 3-4 weeks (Fig. 4). But at 60 DAS, Significant variation was observed in the mean values of plant height of MR_1 (83.00cm), MR_2 (81.00cm) and MR_3 (80.20cm) when compared to MR_0 (60.80cm). However, the values of MR_1, MR_2 and MR_3 didn't vary significantly. The highest plant height was observed in MR_1 (83.00cm) followed by MR_2 (81.00cm) where the lowest in MR_0 (60.80cm) preceded by MR_3 (80.20cm).

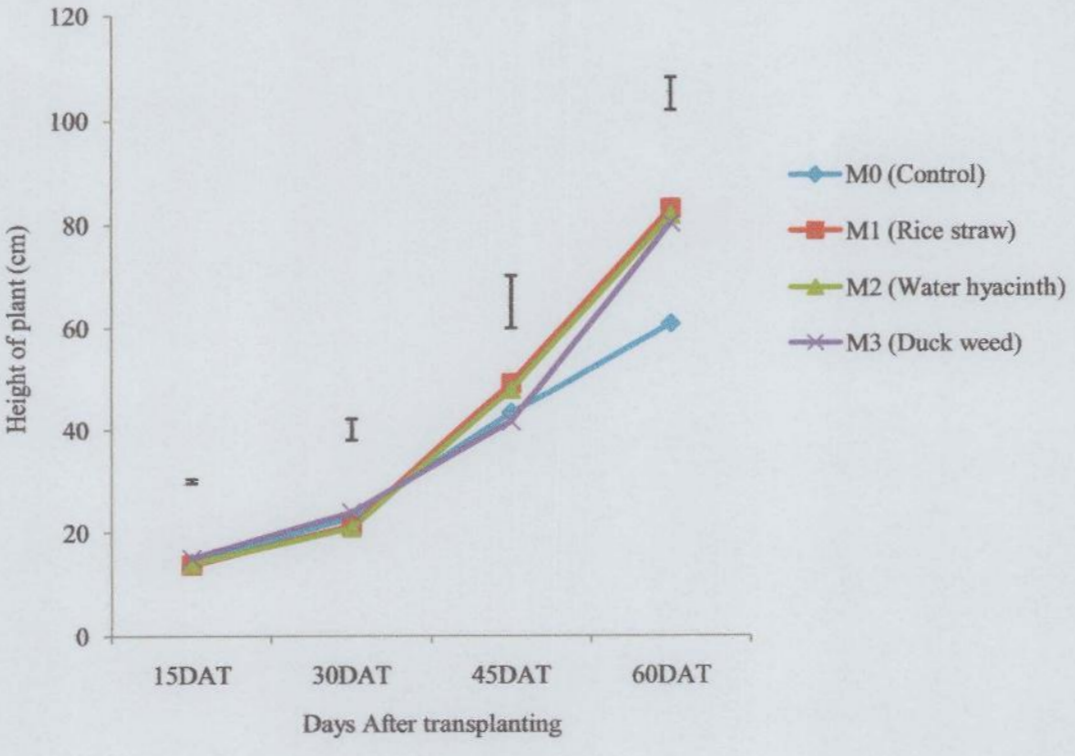

Fig. 4: Effect of different mulch residue on plant height of Tomato at different DAT. (Vertical bars represents $LSD_{0.05}$)

In case of Brinjal, for first few weeks there were no significant differences among the plant heights (Fig. 5). Significant variation due to the effect of mulch residues in plant height at 60 DAS was observed from the mean values of all treatments MR_2 (59.80cm), MR_1 (56.20cm) and MR_3 (54.00cm) compared to MR_0 (48.20cm). The mean value of every treatment differed significantly from one another. The highest plant height was observed from MR_2 (59.80cm) followed by MR_1 (56.20cm) whereas the lowest plant height was observed from MR_0 (48.20cm) preceded by MR_3 (54.00cm).

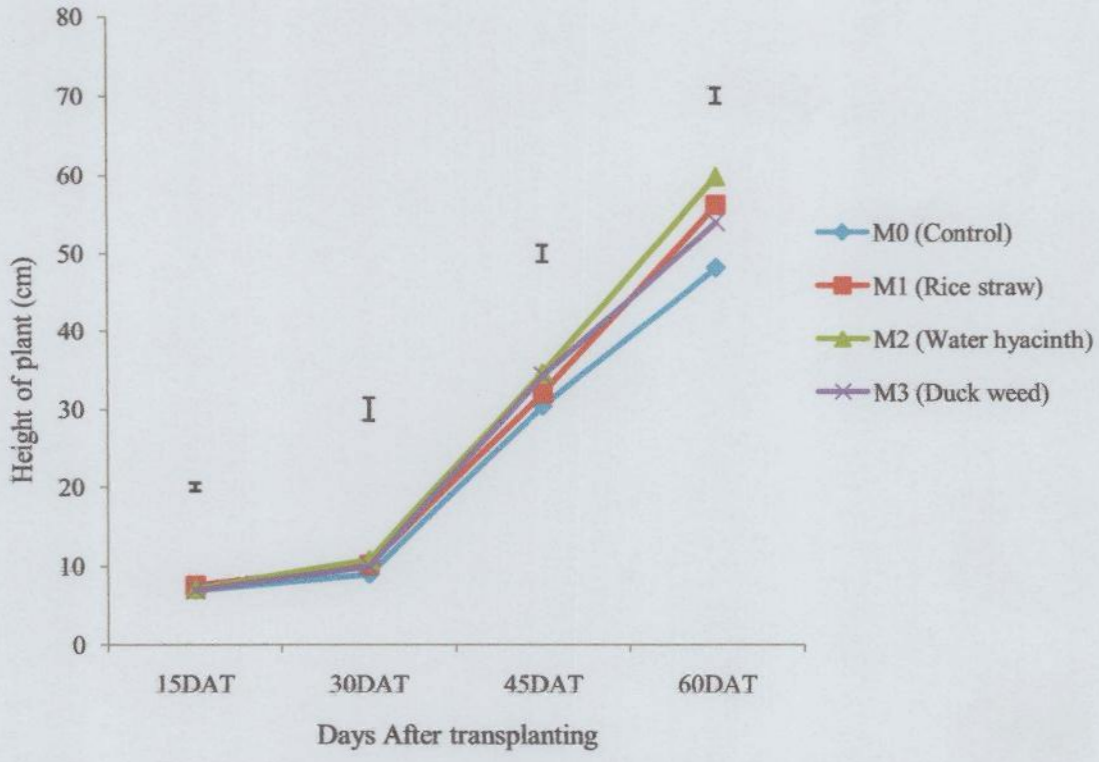

Fig. 5: Effect of mulch residue on plant height of Brinjal at different DAT. (Vertical bars represents $LSD_{0.05}$)

Due to the effect of mulch residues a variation of plant height was observed in plant height from the second week in Knolkhol plants (Fig. 6). Variation in plant height was observed at 60 DAT from treatments MR_2 (55.80cm), MR_1 (52.20cm) and MR_3 (51.60cm) when compared to Control (41.80cm). But the values of MR_2, MR_1 and MR_3 were statistically identical. MR_2 (55.80cm) provided the highest plant height followed by MR_1 (52.20cm) where Control (41.80cm) performed the lowest preceded by MR_3 (51.60cm).

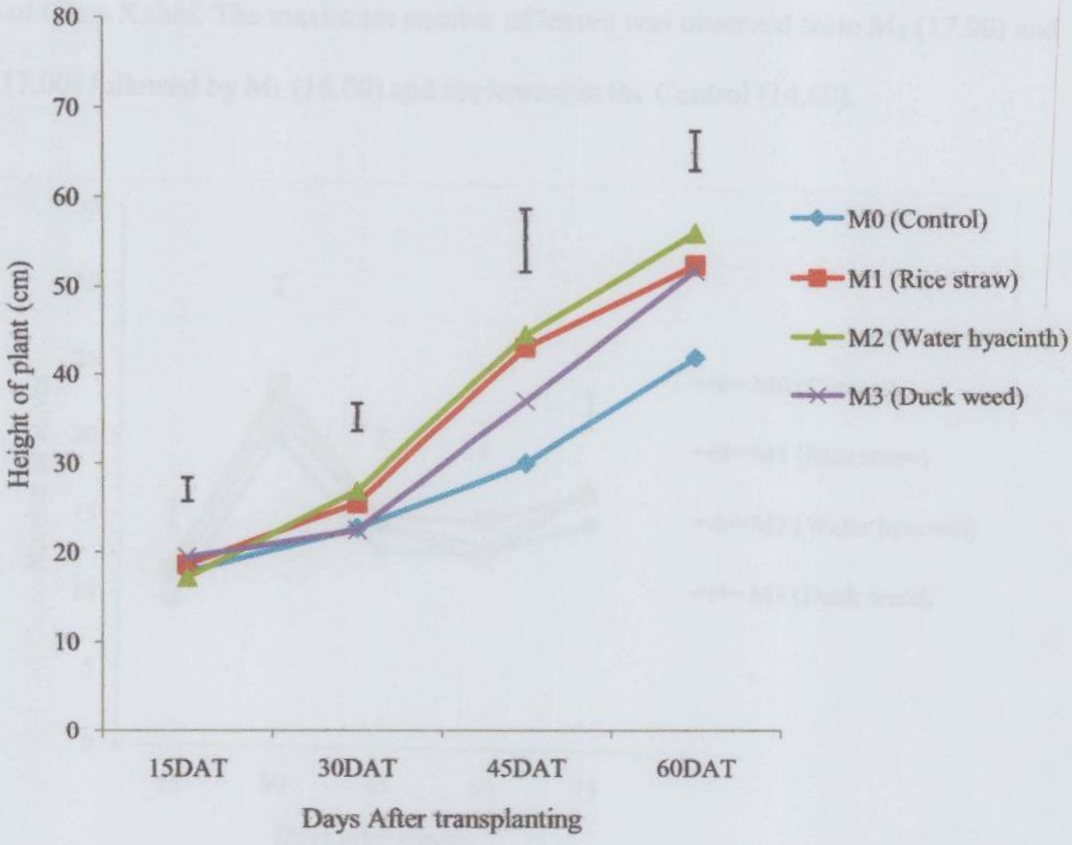

Fig. 6: Effect of mulch residue on plant height of Knolkhol at different DAT. (Vertical bars represents $LSD_{0.05}$)

No significant variations among number of leaves per plant were observed in Okra plants at 15, 30 and 45 DAS (Fig. 8). But, a significant variation in number of leaves at 75DAT was observed from plants due to the influence of mulch materials in M_1 (40.80) and M_3 (39.00) compared to Control (27.60) where M_2 (22.40) didn't vary significantly. The highest number of number of leaves per plant was recorded from M_1 (40.80) followed by M_3 (39.00) and the lowest number was observed from M_2 (22.40). It can be concluded that mulches had a positive effect on number of leaves per plants of Okra plants.

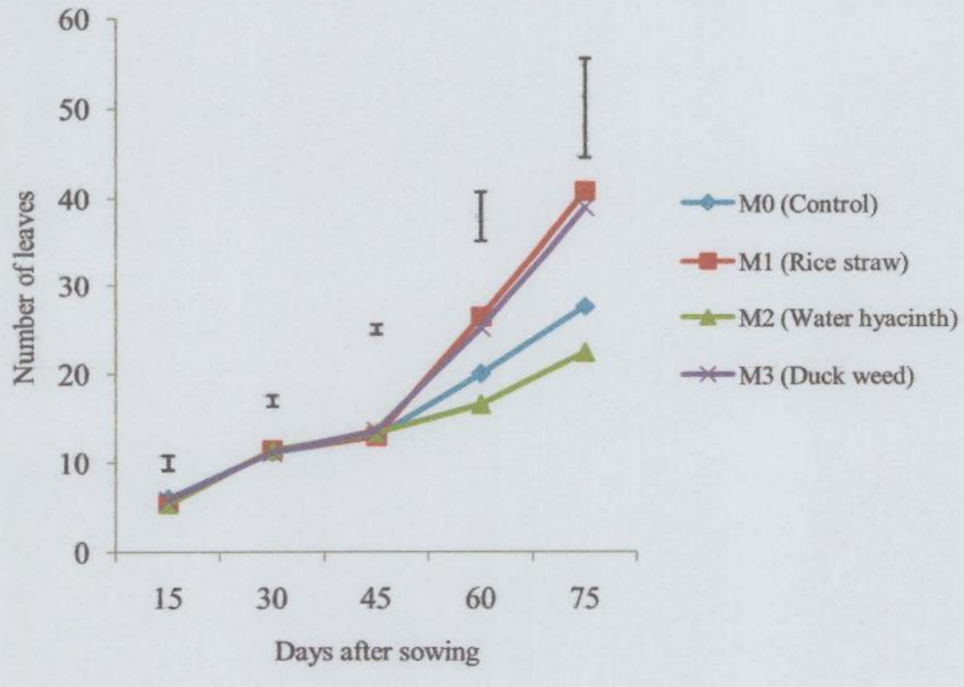

Fig. 8: Effect of different mulchings on number of leaves per plant of Okra at different DAS. (Vertical bars represents $LSD_{0.05}$)

In case of Indian Spinach, number of leaves per plant responded differently at different DAT (Fig. 9). After 45 DAT effect of M_2 was higher compared to other mulching. Significant variation in number of leaves per plant was observed at 75 DAT from M_2 (39.80) compared to Control (28.20) where M_1 (32.00) and M_3 (30.60) remained statistically identical. No significant variation was observed among M_1 (32.00) , M_3 (30.60) and Control (28.20). M_2 (39.80) gave the highest number of leaves per plant followed by M_1 (32.00), M_3 (30.60) and the lowest number of leaves per plant was produced by Control (28.20).

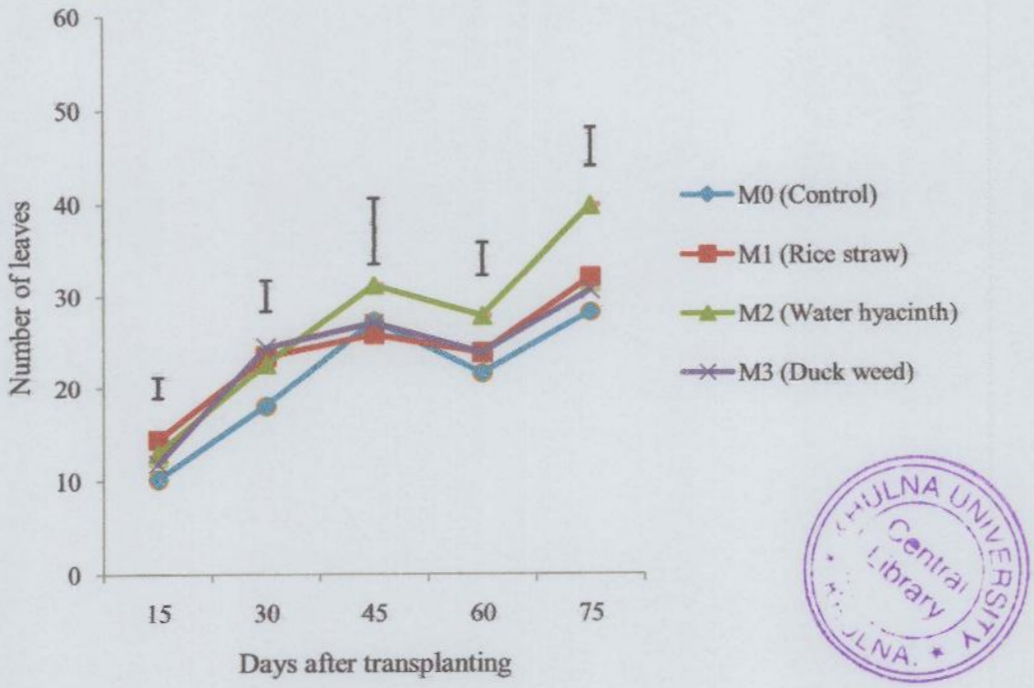

Fig. 9: Effect of different mulchings on number of leaves per plant of Indian spinach at different DAT. (Vertical bars represents $LSD_{0.05}$)

The mean values of number of leaves per Tomato plant at 45 and 60 DAT varied significantly (Fig. 10) due to the effect of mulch residues in MR_3 (76.20), MR_1 (74.40) and MR_2 (71.80) compared to MR_0 (58.20). But the values of MR_3, MR_1 and MR_2 were statistically identical. Maximum number of leaves was observed from MR_3 (76.20) followed by MR_1 (74.40) where minimum number of leaves per plant was observed from MR_0 (58.20) preceded by MR_2 (71.80).

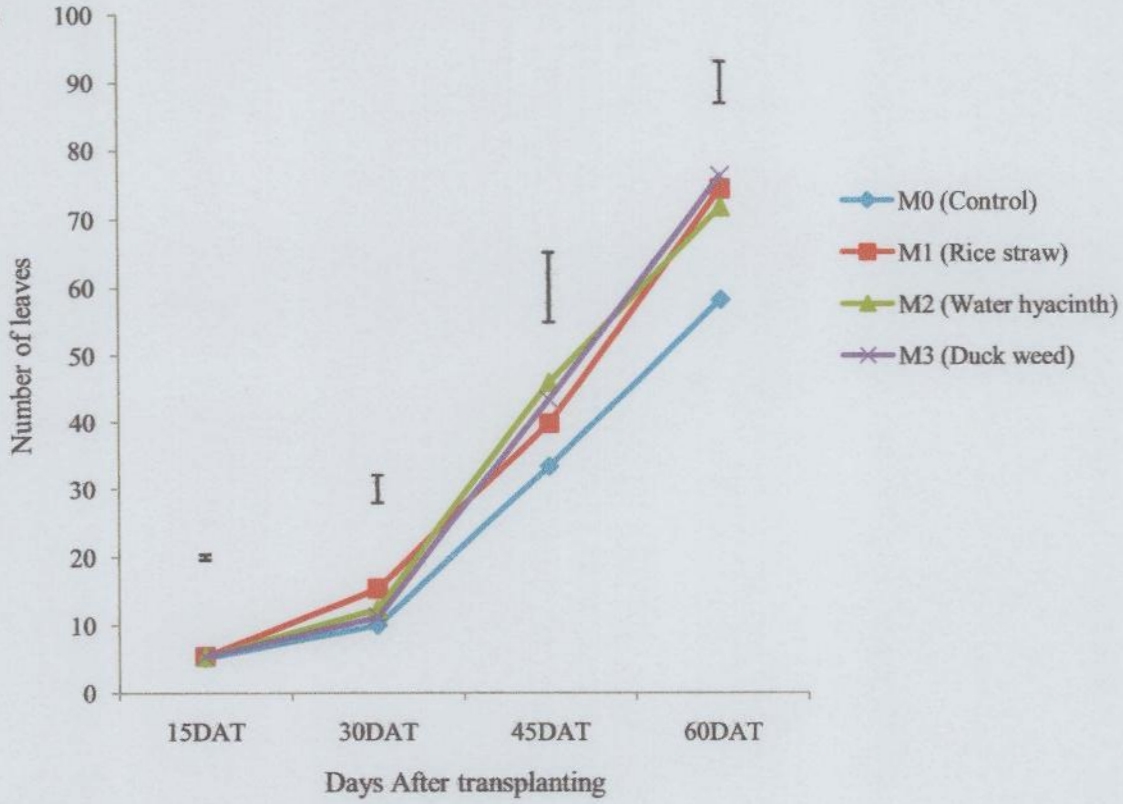

Fig. 10: Effect of mulch residue on number of leaves per plant of Tomato at different DAT. (Vertical bars represents $LSD_{0.05}$)

Number of leaves per plant didn't vary significantly among MR_1, MR_2 and MR_3 due to the effect of mulch residue at 15, 30 and 45 DAT (Fig. 11). A significant variation in number of leaves per plant at 60 DAT was observed due to the effect of mulch residues in the mean values of all treatments MR_2 (64.40), MR_1 (57.80) and MR_3 (54.60) compared to MR_0 (43.00). The mean value of every treatment differed significantly from one another. Maximum number of leaves per plant was observed from MR_2 (64.40) followed by MR_1 (57.80) where the lowest number of leaves per plant was observed from MR_0 (43.00) preceded by MR_3 (54.60).

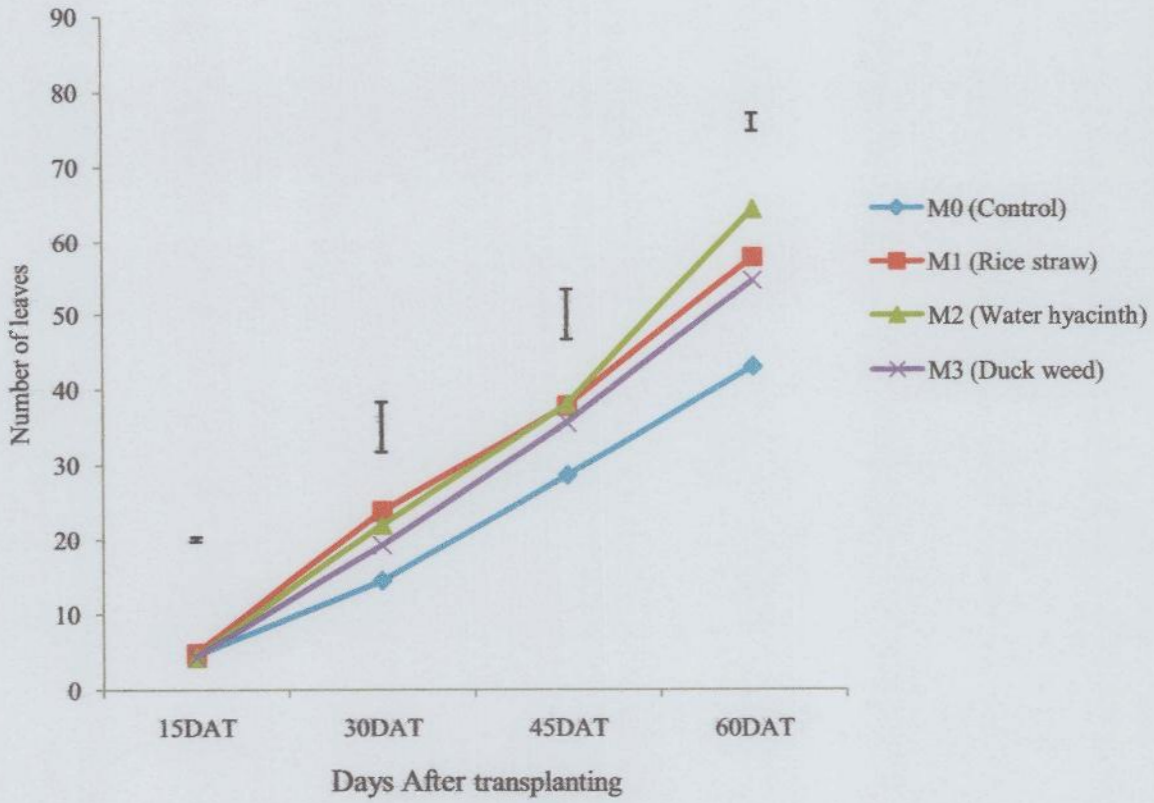

Fig. 11: Effect of mulch residue on number of leaves per plant of Brinjal at different DAT. (Vertical bars represents $LSD_{0.05}$)

In case of Knolkhol, significant variation was observed due to the effect of mulch residues at 60 DAT for the mean values of number of leaves per plant of MR_2 (29.80), MR_3 (27.20) and MR_1 (26.80) when compared to MR_0 (23.80) (Fig. 12). However, the values of MR_3 and MR_1 didn't varied significantly. The highest number of leaves per plant was found in MR_2 (29.80) followed by MR_3 (27.20) where the lowest in MR_0 preceded by MR_1 (26.80).

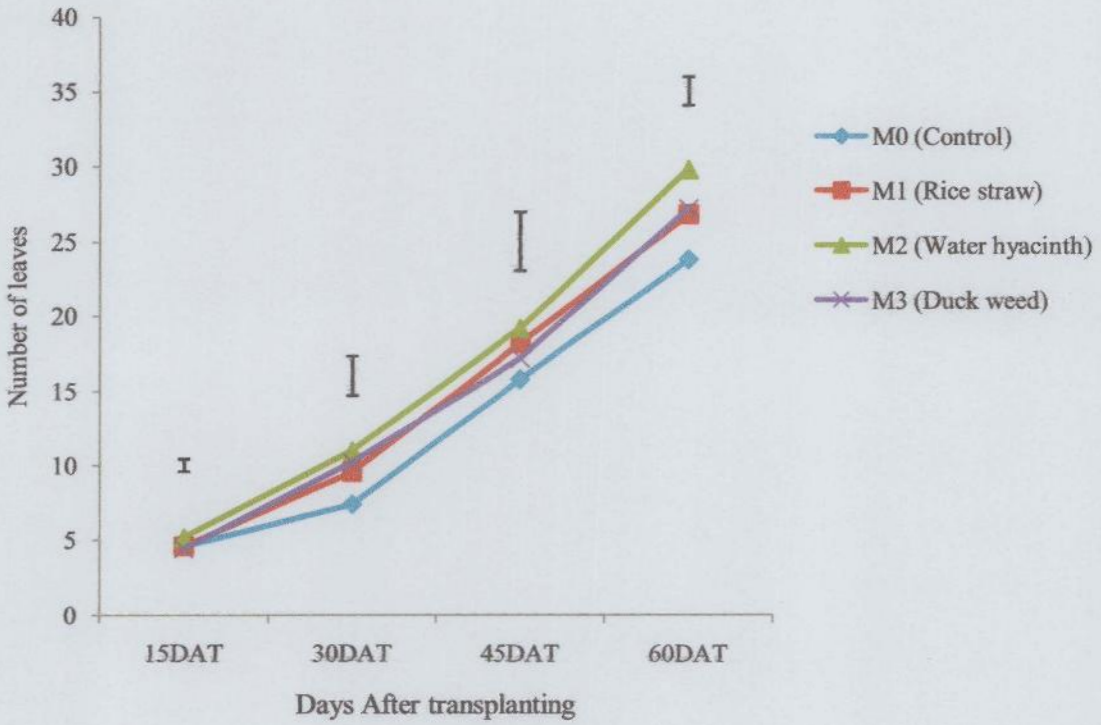

Fig. 12: Effect of mulch residue on number of leaves per plant Knolkhol at different DAT. (Vertical bars represents $LSD_{0.05}$)

4.3 Length of largest leaf

No significant variations in the Length of largest leaf of the Gima Kalmi plants at 75 DAT were observed due to the influence of different treatment (Table: 2). However, numerically the highest Length of largest leaf was given by M_2 (15.80cm) and M_3 (15.80cm) followed by M_1 (15.20cm) and the lowest one found in Control (14.60cm).

Length of plant leaves of Okra plants at 75 DAT varied significantly in M_1 (43.60cm) compared to the Control (33.40cm) where effect of M_3 (39.60cm), M_2 (27.40cm) and Control (33.40cm) remained statistically identical. Also the mean of M_1 (43.60cm) and M_3 (39.60cm) didn't vary significantly. The highest and the lowest length of largest leaf was seen in M_1 (43.60cm) and M_2 (27.4cm) respectively. The second highest length of largest leaf was observed from M_3 (39.60cm) followed by the Control (33.40cm).

In case of Indian Spinach, no significant variation in the Length of largest leaf of the plants at 75 DAT due to the effect of different treatment was observed. The highest length of largest leaf was found from M_3 (17.20cm) followed by M_2 (16.00cm) and M_1 (14.80cm) and the lowest one from Control (14.00cm).

The mean values of length of largest leaf of tomato plants at 60 DAT varied significantly due to the effect of mulch residues in MR_3 (33.40cm), MR_1 (33.00cm) and MR_2 (32.80cm) varied compared to MR_0 (28.80cm). But the values of MR_3, MR_1 and MR_2 were statistically identical (Table: 3). The highest plant height was observed from MR_3 (33.40cm) followed by MR_1 (33.00cm) where the lowest length of largest leaf was observed from MR_0 (28.80cm) preceded by MR_2 (32.80cm).

Table 2: Effect of different mulch on yield and yield contributing characters of different summer vegetables.

Vegetables	Treatments	Length of leaves (cm) 75DAS	Width of leaves (cm) 75DAS	Diameter of plant (cm) 75DAS	No of branch 75DAS	Total yield /plot (Kg)	Total yield /ha (ton)
Gima Kalmi (C_1)	M_0	14.60 a	4.40 a	3.060 a	2.60 b	1.89 d	6.30 d
	M_1	15.20 a	4.54 a	3.240 a	3.40 a	2.91 a	9.70 a
	M_2	15.80 a	4.50 a	3.180 a	3.40 a	2.55 b	8.50 b
	M_3	15.80 a	4.38 a	3.180 a	2.80 ab	2.25 c	7.50 c
	CV%	6.04	4.21	3.84	15.55	3.99	3.99
	$LSD_{0.05}$	1.276	0.2578	0.1688	0.6536	0.08715	0.4401
	LS				*	**	**
Okra(C_2)	M_0	33.40 bc	20.00 bc	4.30 b	4.00 b	1.56 b	5.20 b
	M_1	43.60 a	26.00 a	5.50 a	4.60 ab	1.95 a	6.50 a
	M_2	27.40 c	17.00 c	3.70 b	4.00 b	1.71 b	5.70 b
	M_3	39.60 b	24.00 b	5.32 a	5.20 a	2.16 a	7.20 a
	CV%	17.29	18.27	15.50	14.93	8.91	8.91
	$LSD_{0.05}$	8.576	5.476	1.005	0.9161	0.1510	0.7548
	LS	**	*	**	*	**	**
IndianSpinach(C_3)	M_0	14.0 a	6.10 a	4.22 b	4.20 a	3.06 c	10.20 c
	M_1	14.8 a	6.40 a	4.38 b	4.60 a	3.75 b	12.50 b
	M_2	16.0 a	9.40 a	4.58 a	4.00 a	4.59 a	15.30 a
	M_3	17.2 a	8.70 a	4.34 b	3.80 a	3.93 b	13.10 b
	CV%	13.95	29.35	2.67	14.76	5.98	5.98
	$LSD_{0.05}$	2.979	3.094	0.1630	0.8439	0.2090	1.052
	LS			**		**	**

Means followed by common letters do not differ significantly at 5% level of significance...

** : Significant at 1% level of probability.

* : Significant at 5% level of probability.

Table 3: Effect of different mulch residues on yield and yield contributing characters of different winter vegetable.

Vegetables	Treatments	Length of leaves (cm) 60 DAT	Width of leaves (cm) 60 DAT	Diameter of plant (cm) 60 DAT	No of branch 60 DAT	Total yield/plot (Kg)	Total yield/ha (ton)
Tomato (C_1)	MR_0	28.8 b	22.2 b	5.82b	18.6 b	9.62 c	32.08 c
	MR_1	33.0 a	27.2 a	6.38 a	24.4 a	12.8 b	42.96 b
	MR_2	32.8 a	26.4 a	6.28 a	22.8 a	14.5 a	48.32 a
	MR_3	33.4 a	26.6 a	6.40 a	23.8 a	14.3 a	47.68 a
	CV%	7.56	4.47	3.57	5.93	7.17	7.17
	$LSD_{0.05}$	3.335	1.576	0.3050	1.832	1.056	4.223
	LS	*	**	**	**	**	**
Brinjal (C_2)	MR_0	25.8 c	10.6 c	4.20 d	12.2 b	5.52 b	18.4 b
	MR_1	30.0 b	12.0 b	4.52 c	18.0 a	5.79 b	19.3 b
	MR_2	33.4 a	15.0 a	5.06 a	18.0 a	6.63 a	22.1 a
	MR_3	26.8 c	14.2 a	4.82 b	19.0 a	5.61 b	18.7 b
	CV%	3.19	6.80	2.87	8.44	3.53	3.53
	$LSD_{0.05}$	1.276	1.213	0.1849	1.953	0.1899	0.9537
	LS	**	**	**	**	**	**
Knolkhol (C_3)	MR_0	39.0 b	21.0 b	27.6 c		4.53 c	15.11 c
	MR_1	47.0 a	23.4 a	31.0 b		5.03 b	16.79 b
	MR_2	48.8 a	25.0 a	35.4 a		5.80 a	19.36 a
	MR_3	47.2 a	23.2 a	33.4 ab		5.17 b	17.23 b
	CV%	4.84	7.13	7.27		4.84	4.84
	$LSD_{0.05}$	3.032	2.078	3.190		0.3112	1.141
	LS	**	*	**		**	**

Means followed by common letters do not differ significantly at 5% level of significance…

** : Significant at 1% level of probability.

* : Significant at 5% level of probability.

In case of Brinjal, significant variation in length of largest leaf at 60 DAT was observed from the mean values of treatment MR_2 (33.40cm) and MR_1 (30.00cm) compared to MR_0 (25.80cm). The mean value of MR_3 and MR_0 didn't vary significantly (Table: 3). Maximum in length of largest leaf was observed from MR_2 (33.40cm) followed by MR_1 (30.00cm) where the lowest in length of largest leaf was observed from MR_0 (25.80cm) preceded by (26.80cm).

Effect of mulch residues brought significant variation in the mean values of length of largest leaf of Knolkhol plant. Values at 60 DAT of MR_2 (48.80cm), MR_3 (47.20cm) and MR_1 (47.00cm) varied significantly when compared to MR_0 (39.00cm). However, the values of MR_2, MR_3 and MR_1 didn't vary significantly (Table: 3). The longest leaf was found in MR_2 (48.80cm) followed by MR_3 (47.20cm) where the shortest one in MR_0 (39.00cm) preceded by MR_1 (47.00cm).

4.4 Width of largest leaf

In case of Gima Kalmi, no significant variation in the width of largest leaf of the plants at 75 DAT was observed due to the effect of different treatment (Table: 2). But, numerically the highest width of largest leaf value was produced by M_1 (4.540cm) followed by M_2 (4.500cm) and then Control (4.400cm) whereas the lowest was observed from M_3 (4.380cm).

Significant difference in leaf width Of Okra plants was observed between M_1 (26.00cm) and Control (20.00cm). But M_2 (17.00cm) and Control (20.00cm) were statistically identical. But significant Difference was present between M_3 (24.00cm) and M_2 (17.00cm). Again M_1 (26.00cm) and M_3 (24.00cm) were statistically identical. The

highest value was produced by M_1 (26.00cm) followed by M_3 (24.00cm), Control (20.00cm) and the lowest by M_2 (17.00cm).

No significant variation in the width of largest leaf of the plants at 75 DAT was observed among the Indian Spinach plants due to the effect of different treatment. The highest width of largest leaf was performed by M_2 (9.400cm) followed by M_3 (8.700cm), and M_1 (6.400cm) and the lowest one by the Control (6.100cm).

In case of Tomato, significant variation was observed at 60 DAT due to the effect of mulch residues in the mean values of width of largest leaf of MR_1 (27.20cm), MR_3 (26.60cm) and MR_2 (26.40cm) treatment when compared to MR_0 (22.20cm). However, the values of MR_1, MR_3 and MR_2 didn't vary significantly. Maximum width of largest leaf was seen in MR_1 (27.20cm) followed by MR_3 (26.60cm) where the lowest one in MR_0 (22.20cm) preceded by MR_2 (26.40cm).

Variation in width of largest leaf of Brinjal plants was observed at 60 DAT due to the effect of mulch residues in treatments MR_2 (15.00cm), MR_3 (14.20cm) and MR_1 (12.00cm) when compared to MR_0 (10.60cm). But the values of MR_2, MR_3 and MR_1 were statistically identical. MR_2 (15.00cm) provided the maximum width of largest leaf followed by MR_3 (14.20cm) where MR_0 (10.60cm) performed the lowest preceded by MR_1 (12.00cm).

Effect of mulching on mean values of width of largest leaf of MR_2 (25.00cm), MR_1 (23.40cm) and MR_3 (23.20cm) was observed to be significant in case of Knolkhol at 60 DAT when compared to MR_0 (21.00cm). However, the values of MR_2, MR_1 and MR_3 didn't vary significantly (Table: 3). Maximum width of largest leaf was seen in MR_2 (25.00cm) followed by MR_1 (23.40cm) where the lowest one in MR_0 (21.00cm) preceded by MR_3 (23.20cm).

4.5 Diameter of Plant

No significant variation was observed in the diameter of the plants at 75 DAS due to the impact of different mulching treatment on Gima Kalmi Plants(Table: 2). The highest diameter of leaves was given by M_1 (3.240cm) followed by M_3 (3.180cm) and M_2 (3.180cm) and the lowest one by the Control (3.180cm).

In case of Okra Plant, significant difference in diameter of plant at 75 DAT was observed from M_1 (5.500cm) and M_3 (5.320cm) compared to Control (4.300cm) where M_2 (3.700cm) was identical to the Control (4.300cm). The highest plant diameter was observed from M_1 (5.500cm) followed by M_3 (5.320cm), and the Control (4.300cm) and the lowest in M_2 (3.700cm)

The value of plant diameter of the plots treated with M_2 (4.580cm) differed significantly at 75 DAT compared to the Control (4.220cm) in case of Indian Spinach. But the effect of M_1 (4.380cm), M_3 (4.340cm) and the Control (4.220cm) was statistically identical. The highest mean was found from M_2 (4.580cm) followed by M_1 (4.380cm), and M_3 (4.340cm) whereas the lowest from Control (4.220cm).

The effect of mulch residues had a significant influence on the mean values of diameter of plants of Tomato at 60 DA where values of MR_3 (6.40cm), MR_2 (6.38cm) and MR_1 (6.28cm) treatment varied significantly when compared to MR_0 (5.82cm). However, the values of MR_3, MR_2 and MR_1 were statistically similar. Maximum diameter of plants was found in MR_3 (6.40cm) followed by MR_2 (6.38cm) where the lowest one in MR_0 (5.82cm) preceded by MR_1 (6.28cm).

In case of Brinjal, significant variation in diameter of plants at 60 DAT due to the effect of mulch residues was observed from the mean values of all treatments MR_2 (5.0cm), MR_3 (4.8cm) and MR_1 (4.5cm) compared to MR_0 (4.2cm). The mean value of every

treatment differed significantly from one another. Maximum plant diameter was observed from MR_2 (5.0cm) followed by MR_3 (4.8cm) where lowest plant diameter was observed from MR_0 (4.2cm) preceded by MR_1 (4.5cm).

Variation in plant diameter of Knolkhol was observed at 60 DAT from treatments MR_2 (35.40cm), MR_3 (33.40cm) and MR_1 (31.00cm) when compared to MR_0 (27.60cm). But the values of MR_1 and MR_3 were statistically identical (Table: 3). MR_2 (35.40cm) provided the maximum plant height followed by MR_3 (33.40cm) where MR_0 (27.60cm) performed the lowest preceded by MR_1 (31.00cm).

4.6 Number of Branch

In case of Gima Kalmi, significant variation in means value of number of branch at 75 DAS was observed from M_2 (2.6), M_1 (3.4) compared to the Control. M_3 (2.8) was statistically identical to Control (2.6). The highest number of branch was observed in both M_2 (3.4) and M_1 (3.4) followed by M_3 (2.8) whereas Control (2.8) providing the lowest (Table: 2).

The values of number of branch per Okra plant at 75 DAT from the plots treated with M_3 (5.2) differed significantly compared to the Control (4.0) but the value of M_2 (4.0) and M_1 (4.6) were statistically similar. The difference between mean value of M_3 (5.2) and M_1 (4.6) was statistically insignificant. The highest number of branch was observed from M_3 (5.2) followed by M_1 (4.6) whereas both M_2 (4.0) and the Control (4.0) gave the least number of branches (Table: 2).

In case of Indian Spinach, no significant variation was seen among the treatments for the number of branch per plant at 75 DAT due to the influence of mulching (Table: 2). The

highest value was observed from M_1 (4.6) followed by the Control (4.2) and the lowest value was observed from M_3 (3.8) preceded by M_2 (4.0).

Significant variations were observed at 60 DAT due to the effect of mulch residues in the mean values of number of branch per plant of Tomato (Table: 3). The values of MR_1 (24.40), MR_3 (23.80) and MR_2 (22.80) were significant when compared to MR_0 (18.60). However, the values of MR_1, MR_3 and MR_2 didn't vary significantly. Maximum number of branch was seen in MR_1 (24.40) followed by MR_3 (23.80) where the lowest in MR_0 (18.60) preceded by MR_2 (22.80).

In case of Brinjal, variation in number of branch was observed at 60 DAT from treatments MR_3 (19.00), MR_2 (18.00) and MR_1 (18.00) when compared to MR_0 (12.20). But the values of MR_3, MR_2 and MR_1 were statistically identical. MR_3 (19.00) produced the highest number of branch where MR_0 (12.20) performed the lowest preceded by both MR_2 (18.00) and MR_1 (18.00).

4.7 Yield per Plot

A significant variation in total yield was observed from Gima Kalmi plants due to the influence of mulch materials in M_1 (2.91kg), M_2 (2.55kg) and M_3 (2.25kg) when compared to Control (1.89kg). Plants grown in M_1 (2.91kg) gave the maximum yield followed by M_2 (2.55kg). Yield among those three types of much (M_0, M_1 and M_2) treatment varied significantly (Table: 2). Minimum yield was observed from the Control (1.89kg) preceded by M_3 (2.25kg).

In case of Okra, significant variation in total yield was observed from plants treated with mulch M_3 (2.16kg) and M_1 (1.95kg) compared to Control (1.56kg). But the Yield of M_2 (1.71kg) was statistically similar to Control (1.56kg). The highest yield was given by

plants treated with treatment M_3 (2.16kg) followed by M_1 (1.95kg) and the lowest was observed from Control (1.56kg) preceded by M_2 (1.71kg).

The variations in total yield was significantly different in plots with treatment M_2 (4.59kg), M_3 (3.93kg) and M_1 (3.75kg) compared to the Control (3.06kg) in case of Indian Spinach Plants (Table: 2). Yield of M_3 and M_1 was statistically identical. The highest yield was observed from M_2 (4.59kg) followed by M_3 (3.39kg) whereas the lowest in Control (3.06kg) preceded by M_1 (3.75kg).

In case of Tomato, significant variation was observed due to the effect of mulch residues in the mean values of total yield of MR_2 (14.5 kg), MR_3 (14.3 kg) and MR_1 (12.8 kg) compared to MR_0 (9.6 kg). However, the values of MR_2, MR_3 and MR_2 didn't vary significantly (Table: 3). The highest total yield was recorded from MR_2 (14.5 kg) followed by MR_3 (14.3 kg) whereas the lowest in MR_0 (9.6 kg) preceded by MR_1 (12.8 kg).

Variations in mean value of total yield were observed only in treatment MR_2 (6.63 kg) when compared to MR_0 (5.52 kg) in case of Brinjal plants. But the values of MR_1 (5.79 kg) and MR_3 (5.61 kg) were statistically identical (Table: 3). MR_2 (6.63 kg) provided the highest total yield followed by MR_1 (5.79 kg) where MR_0 (5.52 kg) gave the lowest mean value preceded by MR_3 (5.61 kg).

In case of Knolkhol, the mean value of total yield observed from treatments MR_2 (5.80kg), MR_3 (4.700kg) and MR_1 (5.03kg) was significantly different when compared to MR_0 (4.532kg). But the values of MR_1 and MR3 were statistically identical (Table: 3). MR_2 (5.80kg) provided the highest plant height followed by MR_3 (5.17kg) where MR_0 (4.532kg) produced the lowest preceded by MR_1 (5.03kg).

CHAPTER: V

ECONOMIC ANALYSIS

Input costs for land preparation, seed cost, seedling cost, mulch, fertilizer, irrigation and man power required for all the operations including harvesting of all vegetables were recorded for unit plot and converted into cost per hectare. Prices of the harvested vegetables were considered in market rate basis.

The economic analysis was done in order to find out the most economic treatment of mulch material (Experiment-1) and mulch material residue (Experiment-2) for each vegetable and the most profitable vegetable and mulching/mulching residue combination as well as gross and net return and the benefit cost ratio.

The whole economic analysis of data has been presented in appendix V and VI.

Gross return:

The combinations of vegetables and mulch were significant in respect of gross return. Among them the maximum gross return was obtained from Rice straw treatment in Gima Kalmi plant, Duck weed treatment in Okra Plant and Water hyacinth treatment in Indian Spinach plant (Appendix V).

The combinations of vegetables and mulch residues showed significantly different gross return. Among them the maximum gross return was obtained from Water hyacinth residue treatment in all three types of plant (Appendix VI).

Net return:

The combinations of vegetables and mulch showed significantly different gross return due to the effect of mulch materials. Among them the maximum net return was obtained from Rice straw treatment in Gima Kalmi plant, Duck weed treatment in Okra Plant and Water hyacinth treatment in Indian Spinach plant (Appendix V).

The combinations of vegetables and mulch showed significantly different net return. Among them the maximum net return was obtained from Water hyacinth residue treatment in all three types of plant (Appendix VI).

Benefit cost ratio:

The benefit cost ratio (BCR) was calculated as follows:

$$\text{Benefit cost ratio} = \frac{\text{Gross return per hectare (Tk.)}}{\text{Total cost of production per hectare (Tk.)}}$$

The combinations of vegetables and mulch showed significantly different benefit cost ratio. Among them the maximum benefit cost ratio was obtained from Rice straw treatment in Gima Kalmi plant, Duck weed treatment in Okra Plant and Water hyacinth treatment in Indian Spinach plant (Appendix V).

From economic point of view, it is apparent from the above results that treatment with Rice Straw mulch was most effective for Gima Kalmi Plant, duck weed was most effective treatment for Okra plant and Water Hyacinth mulch was the most effective treatment for Indian Spinach cultivation in the present trial.

Significantly different benefit cost ratio was obtained from the combination of vegetables and mulch residue. Among them the maximum benefit cost ratio was obtained from Water hyacinth residue treatment in all three types of vegetable.

From economic point of view, it is apparent from the above results that treatment with water hyacinth mulch residue was most effective for vegetable cultivation in the present trial (Appendix VI).

plants were produced by plots treated with Rice Straw Mulch (120.8cm) and the highest number of leaf per plant was observed from plots treated with Rice Straw Mulch (40.80). In case of Indian Spinach, the tallest plants were produced by plots treated with Water Hyacinth mulch (68.60cm) and maximum number of leaf per plant was observed from plots treated with Water Hyacinth mulch (39.80).

Again length and width of plant leaves also varied significantly only in Okra compared to mulch materials applied. In case of Gima Kalmi, the longest leaves were produced by plots treated with Water Hyacinth mulch (15.80cm) and widest leaves were observed from plots treated with Rice Straw Mulch (4.540cm). In case of Okra, the longest leaves were produced by plots treated with Rice Straw Mulch (43.60cm) and widest leaves were observed from plots treated with Rice Straw Mulch (26.00cm). In case of Gima Kalmi, the longest leaves were produced by plots treated with Duck Weed mulch (17.20cm) and widest leaves were observed from plots treated with Water Hyacinth mulch (9.400cm).

Mulch materials also exhibited a significant variation on plant diameter (except Gima Kalmi). In case of Gima Kalmi, plants with maximum stem diameter were produced by plots treated with Rice Straw Mulch (3.240cm). In case of Okra it was Rice Straw mulch (5.500cm) In case of Indian Spinach it was Water Hyacinth mulch (4.580cm).

Significant variation also observed due to mulch materials also on number of branch per plant (except Indian Spinach). In case of Gima Kalmi, plants with maximum number of branch were produced by plots treated with both Water Hyacinth mulch (3.4) and Rice Straw mulch (3.4). In case of Okra plants the maximum number of branch was found in Duck Weed mulch (5.2) In case of Indian Spinach it was Rice Straw mulch (4.6).

Variations were also significant due to mulch materials on yield per plot. In case of Gima Kalmi, the maximum yield was produced by the plots treated with Rice Straw mulch

(2.91kg). In case of Okra it was Duck Weed mulch (2.16kg) In case of Indian Spinach it was Water Hyacinth mulch (4.59kg)

When per plot yield was converted to per hectare yield and considered, significant variation also observed due to mulch materials also on per hectare yield. In case of Gima Kalmi, maximum per hectare yield was produced by plots treated with Rice Straw mulch (9.7 ton). In case of Okra plants with maximum yield per hectare was recorded from Duck Weed mulch (7.2 ton) and in case of Indian Spinach it was Water Hyacinth mulch (15.3 ton).

Again in Experiment-2, all mulch residues incorporated with in the soil exhibited significant variation in almost all parameters. Plant height and number of leaves per plant varied significantly on account of mulching residue in all plants. In case of Tomato, the tallest plants were produced by plots treated with Rice Straw Mulch residue (83.00cm) and the highest number of leaf per plant was observed from plots treated with Duck Weed mulch residue (76.20). In case of Brinjal, the tallest plants were produced by plots treated with Water Hyacinth mulch residue (59.80cm) and the highest number of leaf per plant was observed from plots treated with Water Hyacinth mulch residue (64.40). In case of Knolkhol, the tallest plants were produced by plots treated with Water Hyacinth mulch residue (55.80cm) and the highest number of leaf per plant was observed from plots treated with Water Hyacinth mulch residue (29.80).

Again length and width of plant leaves also varied significantly in relation to mulch residue mixed in the field soil. In case of Tomato, the longest leaves was produced by plots consisted of Duck Weed mulch residue (33.40cm) and the widest leaves was observed from plots consisted of Rice Straw Mulch residue (27.20cm). In case of Brinjal, the longest leaves were produced by plots consist of Water Hyacinth mulch residue (33.40cm) and widest leaves were observed from plots with Water Hyacinth mulch residue (15.00cm). In case of Tomato,

the longest leaves were produced by the plots with Water Hyacinth mulch residue (48.80cm) and the widest leaves were observed from Water Hyacinth mulch residue (25.00cm).

Mulch residue also exhibited a significant variation on plant diameter. In case of Tomato, plants with maximum stem diameter were produced by Duck Weed mulch residue (6.400cm). In case of Brinjal (5.060cm) and Knolkhol (35.40cm) it was Water Hyacinth mulch residue.

Significant variation was also observed due to mulch residue on number of branch per plant. In case of Tomato, plants with the maximum number of branch were produced by Rice Straw Mulch residue (24.40). In case of Brinjal plants the maximum number of branch was recorded from Duck Weed mulch residue (19.00).

Variations were also significant due to mulch residue on yield per plot. In case of Tomato, plot with maximum yield was produced by Water Hyacinth mulch residue (14.5 kg). Water Hyacinth mulch residue (6.63 kg) also produced the maximum yield in case of Brinjal and Knolkhol (5.80kg).

When per plot yield was converted to per hectare yield and considered, significant variation also observed due to mulch residue on per hectare yield. In case of Tomato, the maximum per hectare yield was produced by plots consisted of Water Hyacinth mulch residue (724.8 ton). In case of Brinjal plants, the maximum yield per hectare was recorded from Water Hyacinth mulch residue (663.0 ton). In case of Knolkhol it was also Water Hyacinth mulch residue (387.2 ton).

Conclusions:

The study revealed that impact of mulch materials had varied plant to plant, parameter to parameter. A particular mulching is seen to be more influential to the growth, yield and yield contributing characteristics of a particular vegetable.

- Considering the total growth and yield of vegetables in this experiment, it could be concluded that Rice straw mulch was more beneficial than others for Gima Kalmi plant, Duck Weed was more beneficial for Okra plant and Water Hyacinth was more beneficial for Indian Spinach plant.
- But in case of residual effect of mulch materials, Water Hyacinth topped all other Mulch materials. All of three winter vegetables provided maximum yield in plots that contained Water Hyacinth mulch residue. So, it is very clear that water hyacinth have more residual effect than other mulches.
- Gima Kalmi and Rice straw Combination was found to be most beneficial by having maximum Benefit Cost Ratio among all summer vegetable mulching combination. On the other hand, Tomato and Water Hyacinth residue combination provided maximum benefit among all winter vegetable and mulching residue combination.

Recommendation:

So, according to the experiments, it may be suggested that cultivation of Gima Kalmi with application of Rice Straw mulch, Okra with the application of duck weed mulch and Indian spinach with the application of Water Hyacinth mulch will result maximum growth and yield. But when cultivation is being done for long term or all year round especially in a soil with less organic matter, it is suggested to cultivate vegetables with application of Water Hyacinth as mulch material to increase the productivity of soil with its residual effect.

CHAPTER: VII

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APPENDICES

Appendix I: Analysis of variance of the data on yield and yield contributing characters of different summer vegetable influenced by different types of mulching in experiment-1.

Vegetables	Source of variation	Degrees of freedom	Mean Square (M.S) Value														
			Plant Height (cm) 15 DAS	Plant height (cm) 30 DAS	Plant Height (cm) 45 DAS	Plant height (cm) 60 DAS	Plant height (cm) 75 DAS	Number of leaves (cm) 15 DAS	Number of leaves (cm) 30 DAS	Number of leaves (cm) 45 DAS	Number of leaves (cm) 60 DAS	No of leaves 75 DAS	Length of leaves (cm) 75 DAS	Width of leaves (cm) 75 DAS	Diameter of plant (cm) 75 DAS	No of branch 75 DAS	Total yield/plot (Kg)	Total yield/ha (Ton)
Gima kalmi (C_1)	Replication	4	3.700	1.800	3.450	8.300	3.450	1.575	0.200	0.125	0.250	2.250	1.325	0.014	0.006	0.425	0.065	0.719
	Treatment	3	13.917	1.800*	19.783*	12.583	18.450*	4.600	12.067**	4.850*	6.183	6.600	1.650	0.030	0.029	0.850*	0.942**	10.467**
	Error	12	6.000	3.167	3.950	7.500	4.283	1.642	0.733	0.558	2.017	3.017	0.858	0.035	0.015	0.225	0.009	0.102
Okra (C_2)	Replication	4	6.500	7.250	20.800	38.875	398.875	0.700	2.050	0.750	12.550	39.175	28.000	6.625	0.422	1.175	0.027	0.075
	Treatment	3	1.117	34.200	41.400	306.733*	3397.650**	0.450	0.067	0.450	104.583**	395.250**	252.400**	81.250*	3.641**	1.650*	1.049**	3.883**
	Error	12	2.700	15.450	33.900	54.942	731.442	1.367	0.817	0.617	15.917	63.208	38.733	15.792	0.532	0.442	0.324	0.300
Indian spinach (C_3)	Replication	4	4.175	67.300	13.700	7.500	12.500	0.325	4.075	10.550	5.125	18.325	0.875	5.231	0.013	0.075	0.052	0.575
	Treatment	3	8.183	1081.933**	278.800**	199.133**	323.250**	15.91**	40.067**	27.600	33.383*	125.917**	9.800	13.550	0.112**	0.583	1.978**	21.979**
	Error	12	11.642	54.100	116.700	20.133	11.167	2.792	5.942	26.350	6.425	8.958	4.675	5.040	0.014	0.375	0.053	0.583

**: Significant at 1% level of probability.

*: Significant at 5% level of probability.

Appendix II: Analysis of variance of the data on yield and yield contributing characters of different winter vegetable influenced by different types of mulching residues in experiment-2.

Vegetables	Source of variation	Degrees of freedom	Mean Square (M.S.) Value												
			Plant height (cm) 15 DAT	Plant height (cm) 30 DAT	Plant height (cm) 45 DAT	Plant height (cm) 60 DAT	Number of leaves (cm) 15 DAT	Number of leaves (cm) 30 DAT	Number of leaves (cm) 45 DAT	No of leaves 60 DAT	Length of leaves (cm) 60 DAT	Width of leaves (cm) 60 DAT	Diameter of plant (cm) 60 DAT	No of branch 60 DAT	Total yield/plot (Kg)	Total yield/ha (Ton)
Tomato (C_1)	Replication	4	1.625	1.825	63.675	7.175	1.075	5.375	83.825	37.200	2.625	2.575	0.093	1.200	1.740	19.332
	Treatment	3	1.383	9.783*	65.917	550.850**	0.050	26.850	149.117	333.650**	23.067*	26.267**	0.369**	34.267**	25.383**	282.037**
	Error	12	2.258	2.658	36.875	20.308	0.342	9.142	55.658	20.567	5.858	1.308	0.049	1.767	0.854	9.391
Brinjal (C_2)	Replication	4	0.300	2.125	7.925	4.175	0.425	18.825	29.625	2.300	2.125	1.175	0.019	3.175	0.039	0.778
	Treatment	3	0.400	2.800	19.333*	118.183**	0.183	83.917*	96.933*	400.583**	59.067**	20.317**	0.694**	48.133**	1.228**	25.444**
	Error	12	0.567	4.258	2.458	1.975	0.225	22.792	24.558	3.000	0.858	0.775	0.018	2.008	0.043	0.852
Knolkhol (C_3)	Replication	4	5.875	11.925	46.125	1.950	0.425	4.175	9.575	1.700	7.375	2.825	4.825		0.016	0.175
	Treatment	3	4.583	23.267*	222.733**	179.650**	0.600	11.917	10.533	30.200**	97.133**	13.517*	56.317**		1.379**	15.315**
	Error	12	3.875	5.225	26.692	10.150	0.392	3.542	8.075	1.876	4.842	2.725	5.358		0.062	0.686

**: Significant at 1% level of probability.

*: Significant at 5% level of probability.

Appendex III. Mean monthly maximum and minimum temperature, relative humidity and total rainfall in the study area during June 2015 to May 2016.

Year	Months	Temperature (^{0}C)		Relative humidity (%)	Total rainfall (mm)
		Monthly average Maximum	Monthly average Minimum		
2015	June	33.5	26.8	84	318
	July	31.6	25.9	91	924
	August	32.6	26.7	87	371
	September	33.3	26.2	86	293
	October	33.1	24.3	82	83
	November	30.8	20.3	81	3
	December	26.3	16.6	85	6
2016	January	25.8	13.5	80	0
	February	30.3	19.4	78	97
	March	33.9	22.6	75	5
	April	36.3	26.7	75	54
	May	35.1	25.3	78	350

Source: Bangladesh Metrological Department, Regional Inspection Centre, Gollamari, Khulna, Bangladesh.

Appendix IV: Chemical analysis of soil from experimental field.

Initial Soil Test	Soil pH	EC (dS /m)	Organic matter (%)	Potassium (mg/100g soil)	Total Nitrogen (%)	Phosphorus (μ g/ g soil)	Sulpher (μ g/ g soil)	Zinc (μ g/ g soil)
Experiment-1	8.0	5.5	2.13	0.27	0.124	9.39	130.26	0.29
Experiment-.2	7.6	5.1	2.46	0.49	0.135	9.89	111.11	0.34

Appendix V: Cost and return analysis in different summer vegetable production in experiment-1.

Vegetable	Treatment	Economic yield (t/ha)	Income ('000 tk/ha)	Total cost of production ('000 tk/ha)	Net return ('000 tk/ha)	Benefit cost ratio (BCR)
Gima Kalmi (C_1)	Control (M_0)	6.3 d	189.0 d	120	69.00 d	1.575 d
	Rice Straw (M_1)	9.7 a	291.0 a	135	156.0 a	2.156 a
	Water Hyacinth (M_2)	8.5 b	255.0 b	130	125.0 b	1.962 b
	Duck Weed (M_3)	7.5 c	225.0 c	130	95.00 c	1.731 c
	CV	3.99%	3.99%		8.62%	4.09%
	Level of Significance	**	**		**	**
Okra (C_2)	Control (M_0)	5.2 b	156.0 b	120	36.00 c	1.300 b
	Rice Straw (M_1)	6.5 a	195.0 a	135	60.00 b	1.444 b
	Water Hyacinth (M_2)	5.7 b	171.0 b	130	41.00 bc	1.315 b
	Duck Weed (M_3)	7.2 a	216.0 a	130	86.00 a	1.662 a
	CV	8.91%	8.91%		29.47%	9.09%
	LS	**	**		**	*
Indian Spinach (C_3)	Control (M_0)	10.2 c	204.0 c	140	64.00 c	1.457 c
	Rice Straw (M_1)	12.5 b	250.0 b	155	95.00 b	1.613 b
	Water Hyacinth (M_2)	15.3 a	306.0 a	150	156.0 a	2.040 a
	Duck Weed (M_3)	13.1 b	262.0 b	140	112.0 b	1.747 b
	CV	5.98%	5.98%		14.31%	6.01%
	LS	**	**		**	**

Means followed by common letters do not differ significantly at 5% level of significance...

**: Significant at 1% level of probability.

*: Significant at 5% level of probability.