ALLELOPATHIC EFFECTS OF RAPESEED/MUSTARD VARIETIES ON LENTIL AND ITS ASSOCIATED WEEDS

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JUNE, 2013

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A Thesis

Submitted to the Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (M.S.)

IN

AGRONOMY

Semester: January–June, 2013

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CERTIFICATE

This is to certify that the thesis entitled, **"ALLELOPATHIC EFFECTS OF RAPESEED/MUSTARD VARIETIES ON LENTIL AND ITS ASSOCIATED WEEDS"** submitted to the **Faculty of Agriculture,** Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) IN AGRONOMY,** embodies the results of a piece of bona fide research work carried out by **SANTOSH KUMAR PAUL,** Registration. No. 05-01576, under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information as has been availed of during the course of this investigation has duly been acknowledged.

Dated:

Dhaka, Bangladesh

(Professor Dr. Parimal Kanti Biswas)

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ACKNOWLEDGEMENT

All praises are due to the Almighty God Bhagban Shreekrishna , the great, the gracious, merciful and supreme ruler of the universe to complete the research work and thesis successfully for the degree of Master of Science (MS) in Agronomy.

The author expresses the deepest sense of gratitude, sincere appreciation and heartfelt indebtedness to his reverend research supervisor Prof. Dr. Parimal Kanti Biswas, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for his scholastic guidance, innovative suggestion, constant supervision and inspiration, valuable advice and helpful criticism in carrying out the research work and preparation of this manuscript.

The author deems it a proud privilege to acknowledge his gratefulness, boundless gratitude and best regards to his respectable co-supervisor Prof. Dr. Shahidul Islam, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for his valuable advice, constructive criticism and factual comments in upgrading the research work.

The author expresses his unfathomable tributes, sincere gratitude and heartfelt indebtedness from his core of heart to Prof. Dr. Alok Kumar Paul Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka , whose blessing, inspiration, sacrifice, and moral support helps to build up his life and paved to way of his higher study.

Special appreciation and warmest gratitude are extended to his esteemed teachers Professor Dr. Md. Hazrat Ali, Prof. Dr. A.K.M. Ruhul Amin, Prof. Dr. Md. Fazlul Karim, Prof. Dr. Tuhin Suvra Roy, Prof. Dr. H. M. M. Tariq Hossain and all other teachers specially Md. Hassanuzaman, Md. Anisur Rahman, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka who provided creative suggestions, guidance and constant inspiration from the beginning to the completion of the research work. Their contribution, love and affection would persist in his memory for countless days.

The author expressess his heartiest thanks to his dearest friends Sunando, Piu, Mamun, Babu, Palash, Apu, Moni, Bablu, Ariful, Rosy, Rimu, Jesmin, Lipi, Mousumi, Tahmina, Sajib, Noor Ali, Roni, Sufol, Kaushik, Shyamol, Tonmoy, Subal, Jony, Himel, Satu, Rokon, Torikul, Shahin, Proshanto, Palash, Lalit, Falguni, Munni, Rupa, Laila, Ratna, intimate junior Shariar, Kamran, Nizam, Pijush, Dipayon, Ahad, Rocky, Apurbo, Sudip, Shiblu, Raton, Ratina, Tania, Mitu, Debu, Mishad, Pallab, *Monisha, Kalpataru, Shrayoshi, Pritha, Swapna, Himanshu, Sabbir and Juel for their endless and active co-operation during the entire period of the research..*

The author expresses his cordial thanks to his roommates Shawon, Rabbani, Ripon Vai, Ansary Vai, Mannan Vai, Nitun Vai, Milu, Oli, Shahin, Shuvo, Sher-e-Bangla Agricultural University, Dhaka for their encouragement and active co-operation during the entire period of the research.

The author grateful to Jhorna Rani Roy, Siddhartho Shankor Paul, Prof. Dr. Shah-E- Alom, Dr. Md. Rafiqul Islam Mondal, Ajay Kumar Paul, for helping him directly and indirectly in his research work.

The author also expressess his special thanks to Section Officer, Lab. Assistants and other office staffs of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for their extended and heartiest helps during the research work.

The author expresses his unfathomable tributes, sincere gratitude and heartfelt indebtedness from his core of heart to his parents, whose blessing, inspiration, sacrifice, and moral support opened the gate and paved to way of his higher study. The author also expresses his indebtedness to Moli Rani Basu, Sambhu Basu, Rahit Basu, Komol singha and his relatives for their love and well-wishing for him.

The Author

ALLELOPATHIC EFFECTS OF RAPESEED/MUSTARD VARIETIES ON LENTIL AND ITS ASSOCIATED WEEDS

SANTOSH KUMAR PAUL

ABSTRACT

The experiment was conducted at the Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka from November, 2011 to March, 2012 to find out the allelopathic effect of *Brassica* biomass on weed control and yield of lentil. There were eleven treatments in the experiment. The treatment of the experiment consisted green *Brassica* biomass and water extract of dry *Brassica* biomass. Green *Brassica* biomass (30 days old) was incorporated in the soil at the sowing time of lentil @ 2.6 tha^{-1}. Extracted water of dry *Brassica* biomass of each variety were sprayed two times (30 & 60 DAS of lentil) in the specific plot @1.3 t 6666 L^{-1} water ha^{-1}. The treatments were-T_1 = Control, T_2 = Tori 7-Biomass incorporated @2.6 t ha^{-1} at sowing, T_3 = Tori 7-Dry matter water extract spray @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_4 = BARI Sarisha8-Biomass incorporated @2.6 t ha^{-1} at sowing, T_5 = BARI Sarisha8-Dry matter water extract spray @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_6 = BARI Sarisha11-Biomass incorporated @2.6 t ha^{-1} at sowing, T_7 = BARI Sarisha11-Dry matter water extract spray @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_8 = BARI Sarisha13-Biomass incorporated @2.6 t ha^{-1} at sowing, T_9 = BARI Sarisha13-Dry matter water extract spray @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_{10} = BARI Sarisha15-Biomass incorporated @2.6 t ha^{-1} at sowing, T_{11} = BARI Sarisha15-Dry matter water extract spray @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil. The highest no. of weeds m^{-2} both at 30 and 60 DAS were observed in treatment T_1 (164.00 and 169.00 respectively) and lowest in T_2 (62.00) and T_7 (70.00) while highest dry weight of weeds m^{-2} both at 30 and 60 DAS were found in treatment T_1 (4.80g and 16.10g respectively) and minimum in T_9 (1.17g) and T_2 (6.63g) respectively. At harvest the maximum plant height (34.81cm) and dry weight $plant^{-1}$ (3.83g) were found in treatment T_{11} and T_7 and minimum in T_5 (23.99cm) and T_6 (2.47g) respectively. The highest branches $plant^{-1}$(5.17), pods $plant^{-1}$(71.70), grains pod^{-1} (1.93), 1000 grains wt. (20.37g) were found in treatment T_8, $T_{10,}$ T_8 and T_8 respectively. But lowest branches $plant^{-1}$ (3.83), pods $plant^{-1}$ (33.53), grains pod^{-1} (1.70), 1000 grains wt.(18.07gm) were found in treatment T_{11}, $T_{3,}$ T_7 and T_2 respectively. There is a significant result on biological yield, grain yield, straw yield, harvest index and shelling percentage. The highest biological yield (2.83tha^{-1}), grain yield (0.95tha^{-1}), straw yield (2.17tha^{-1}), harvest index (39.23%) and shelling percentage (29.60%) were observed in treatment T_{10}, T_{11}, T_{10}, T_{11} and T_2 respectively. The lowest biological yield (2.10 tha^{-1}), grain yield (0.52 tha^{-1}), straw yield (1.13 tha^{-1}), harvest index (25.17%) and shelling percentage (19.70 %) were found in treatment T_4, T_4, T_4, T_6 and T_{10} respectively.

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CHAPTER 1

INTRODUCTION

The lentil (*Lens culinaris*) is an edible pulse/bean. It is a bushy annual plant of the legume family, grown for its lens-shaped seeds. It is about 40 centimeters (16 inches) tall and the seeds grow in pods, usually with two seeds in each. Sowing time of lentil is Mid-October to Mid-November and harvesting time is Mid-February to Mid-March. Lentils have been part of the human diet since the aceramic (pottery nonproducing) Neolithic times, being one of the first crops domesticated in the Near East. Archeological evidence shows they were eaten 9,500 to 13,000 years ago. Lentil colors range from yellow to red-orange to green, brown and black (Leah, 2011).

With about 30% of their calories from protein, lentils have the third highest level of protein, by weight, of any legume or nut, after soybeans and hemp (BBC, 2011). Proteins include the essential amino acids isoleucine and lysine, and lentils are an essential source of inexpensive protein in many parts of the world, especially in West Asia and the Indian subcontinent, which have large vegetarian populations (http:/www.glisonline.com). Lentils are deficient in two essential amino acids, methionine and cysteine(North Dakota State University, 2009). However, sprouted lentils contain sufficient levels of all essential amino acids, including methionine and cysteine (http:/www.bitterpoison.com). Lentils also contain dietary fiber, folate, vitamin B_1, and minerals. Red (or pink) lentils contain a lower concentration of fiber than green lentils (11% rather than 31%) (USDA nutrient database). Health magazine has selected lentils as one of the five healthiest foods. (Raymond, 2006). Lentils are often mixed with grains, such as rice, which results in a complete protein dish. Lentils also have antinutritional factors, such as trypsin inhibitors and relatively high phytate content. Trypsin is an enzyme involved in digestion, and phytates reduce the bioavailability of dietary minerals (Kumar *et al.*, 2007). Lentils are relatively tolerant to drought, and are grown throughout the world.

The FAO reported that the world production of lentils for calendar year 2009 was 3.917 million metric tons, primarily coming from Canada, India, Turkey and the United States. About a quarter of the worldwide production of lentils is from India, most of which is consumed in the domestic market. Canada is the largest export producer of lentils in the world, and Saskatchewan is the most important producing region in Canada. Canada estimates that Canadian lentil production for the 2009/10 year is a record 1.5 million metric tons (http:/www.vrg.org). Lentil is an important pulse crop in Bangladesh covering an area of 162 thousands hectares of land with an annual production of 211 thousands metric tons (BBS, 2012 and Mian *et al.*, 2012). The average yield of lentil is very low compared to that of the advanced countries. In order to meet the ongoing food deficit and to cope with the food demand for the increasing population, lentil production needs to be increased in Bangladesh. The scope of increasing the cultivated land is limited in Bangladesh due to occupation of land for accommodating the ever growing population. So, the only way to meet the food demand is to increase the total production as yield per unit area. The cultivation cost of different crops is gradually increasing due to the higher prices of inputs and non-availability of laborers. The soil health of Bangladesh is tremendously deteriorated due to intensive agriculture that results lower organic matter status of the soil and causes lower yield. Hence, emphases have to be given on low cost, high profit and environmentally safety agriculture. Management plays an important role on crop production of which weed control is an important task that involves a lot of production cost. There are many factors responsible for low yield, of which weed, the natural enemy of lentil that reduces its yield if not properly controlled. Controlling weeds by mechanical means or by using herbicide is uneconomic due to labour shortage as well as soil, water and environment hazards. Weeds cause enormous losses to crops even more than other pests worldwide. Oerke and Dehne (1997) found that weeds cause around 33% of total crop loss in Asia and other countries. On an average 37.3% of crop produce is damaged by weeds in Bangladesh (Karim *et al.*, 1998) that valued approximately Tk. 59665.7 million (Karim, 2008). Production losses in

Bangladesh due to weeds as 33.2% in food crops, 41.3% in cereals, 31.9% in pulses, 40.8% in oilseed crops, 34.2% in fibre crops and 40.3% in rice. However, an average of 13.1% of crop reproduce is actually lost in the farmers fields even after adopting traditional weed control measure (Mamun, 1990).

Weed management is a most expensive step in crop production due to unavailability of human labour in Bangladesh. As a result the alternate way to control weeds by the use of herbicide is gradually increased. The herbicide use in Bangladesh from 1998 to 2007 is increased from 239.15 mt to 3825.29 mt, the increase rate was 1499.54% (Karim, 2008). The residual effect of the herbicides to the soil, water, environment and health was not yet evaluated properly. Although weed management practices like hand weeding and herbicide application are effective in weed control but are uneconomical due to higher costs (Cheema *et al*., 2003a). Moreover the chemical weed control method is hazardous for health and causes environmental pollution. Managing croplands according to nature's principles will reduce weed problems. Some crops are especially useful because they have the ability to suppress other plants that attempt to grow around to them.

Brassica is a genus of plants in the mustard family Brassicaceae. The members of the genus are collectively known as cruciferous vegetables, cabbages, or mustards. Crops from this genus are sometimes called *cole crops*, which is derived from the Latin *caulis,* meaning *stem or cabbage* (http:/www.wordnik.com). Due to their agricultural importance, *Brassica* plants have been the subject of much scientific interest. They provide high amounts of vitamin C and soluble fiber and contain multiple nutrients with potent anticancer properties: 3,3'-diindolylmethane, sulforaphane and selenium (Hintze, 2005).

Common types of *Brassica* used for food. But it has some allelopathic effect to control weeds of other crop field. Allelopathy refers to a plant's ability to chemically inhibit the growth of other plants. Allelopathy is a biological phenomenon by which an organism produces one or more biochemicals that influence the growth, survival, and reproduction of other organisms. These biochemicals are known as allelochemicals and can have beneficial (positive allelopathy) or detrimental (negative allelopathy) effects on the target organisms. Allelochemicals are a subset of secondary metabolites (Nancy, 2003). Allelopathy is characteristic of certain plants, algae, bacteria, coral, and fungi.

Use of allelopathy (an eco-friendly measure) as an important ecological phenomena to control weeds in different crops is now practicing worldwide (Mansoor *et al*., 2003; Cheema *et al*., 2002; Khan *et al*., 2004; Xuan *et al*., 2005a; Inderjit, 2002 and Biswas *et al*., 2008). The most common effects of allelochemicals may occur through leaching, volatilization, root exudation and the death and decay of the fallen plant parts are either via biotic or abiotic means (Anoya *et al*., 1990). In respect of soil, environment and health concern, allelopathic research to control weeds progress tremendously throughout the world but Bangladesh is lies far behind. Batish *et al*. (2008) from India reported that allelopahy if suitably manipulated, can help to control harmful weeds in an eco-friendly way and thus maintain soil sustainability since the allelochemicals are biodegradable and provide several other advantages. The allelopathic effect to control weeds by young rye plant was reported by Fomsgaard *et al*. (2008), rice cultivar by Noguchi and Salam (2008), different plant residues by Mahmood *et al*. (2008b) and rapeseed and mustard biomass by Biswas *et al*. (2008).

Rapeseed and Mustard is one of the most useful allelopathic cover crop that reduced total weed biomass in Soybean by 40 - 49 % (Krishnan *et al*., 1998) and in wheat (Biswas *et al.*, 2008). Dhima *et al.* (2006) also reported allelopathic potential of the winter cereal extracts on large crabgrass and sugar beet. Similarly soil incorporation of sunflower residues significantly reduced the weeds by 66% compared to the control (Ata and Jamil, 2001). So the use of allelopathic crop residues incorporated with soil to control weeds could be a simple and easy technique for weed control. Weed suppression is effective when crop residues left undisturbed on the soil surface but the effect is lost when tilled into the soil (Sheila, 1986). Putnam and Defrank (1983) reported that weeds that were reduced by rye mulch included ragweed (43%), pigweed (95%) and common purslane (100%). Worsham (1991) & Schilling *et al*. (1986) reported 68-80% reduction of broadleaf weeds by rye. Anon (1993) reported allelopathic effect of rapeseed and showed 90% reduction of yellow nutsedge on sweet potatoes. Yenish and Worsham (1993) also reported highest weed control by rye application. Boydston and Hang (1995) reported that all members of the mustard family (Brassicaceae) contain mustard oils that inhibit plant growth and seed germination. The concentration of allelopathic mustard oils varies with species and variety of mustard. Sullivan (2003) reported that crop residues when left on the soil surface, can be expected to reduce weed emergence by 75 to 90%. An attempt was therefore desired to undertake a study on the role of *Brassica* having 5 different varieties and biomass of them on weed management, growth and yield of lentil. Considering the above context the experiment was designed with the following objectives:

a) To identify the allelopathic effects of *Brassica* varieties on the growth and population of weed.

b) To identify the effect of *Brassica* varieties on the growth and yield of lentil.

c) To find out the possibilities for using allelopathy to improve overall potentiality of weeds and crops in natural weed management.

d) To reduce the use of chemical herbicides in lentil cultivation.

CHAPTER 2

REVIEW OF LITERATURE

The continuous and unbalanced use of chemical herbicides under intensive cropping systems has been considered to be the main cause for declining crop yield and environmental degradation. Using allelopathy in controlling weeds and increasing yield of different crops was studied by many researchers in the world. Lentil is an important pulse crop that attracted less concentration in respect of various aspects. Lentil yield may be reduced significantly when weeds compete with lentil plants for light, water, and minerals. Weeds may also inhibit lentil growth through release of allelopathic chemicals that are toxic to lentil plants. Weeds or weed seeds contaminating harvested grain may reduce quality. Weeding is a common problem for the cultivation of this crop. Manual weed control incurs high cost although herbicidal control of weed is not cost effective and eco-friendly. Very few research works related to growth, yield and development of lentil variety with eco-friendly weed control through allelopathy have been carried out in Bangladesh. However, some research related to the use of allelopathic effect in controlling weeds in different crops have so far been done at home and abroad which have been reviewed in this chapter under the following heads.

2.1 Effect of previous crop or cover crop

2.1.1 Effect on growth characters

Rahman *et al.* (2012a) stated that land with *Brassica* and application of 35 days old *Brassica* biomass @ 0.5 -1.0 kg m^{-2} increased growth of wheat.

Chaichi and Edalati-Fard (2005) studied the allelopathic effects of chickpea root extracts on germination and early growth of crops in rotation. Seed germination rate, germination percent, plant height, shoot dry weight and shoot/root ratio of crops were affected by different treatments. Seed germination rate of crops after chickpea line 5436 was significantly reduced after four weeks. Seed germination percentage increased as the crops were sown two weeks after chickpea physiological ripening. The crop height followed an increasing trend as they were sown later after physiological ripening of chickpea lines. The root extracts of line 4488 significantly reduced soybean biomass production. However, under the same conditions it enhanced biomass production of sorghum. The severity of chickpea root extracts inhibitory effects on crops was dependent on chickpea cultivar as well as the genetic characteristics of crops in rotation.

Smith *et al.* (2001) conducted two studies to determine if selected grass and dicot species had an allelopathic interaction with pecan (*Carya illinoinensis* Wangenh. C. Koch). Leachate from pots with established grasses or dicots was used to irrigate container-grown pecan trees. Leachates from bermudagrass [*Cynodon dactylon* (L.) Pers.], tall fescue (*Festuca arundinacea* Shreb. cv. Kentucky 31), redroot pigweed (*Amaranthus retroflexus* L.), and cutleaf evening primrose (*Oenothera laciniata* Hill) reduced leaf area and leaf dry weight about 20% compared to the controls. Bermudagrass, tall fescue, and primrose leachate decreased pecan root weight 17%, trunk weight 22%, and total tree dry weight 19% compared to the control.

2.1.2 Effect on yield and yield contributing characters

Rahman *et al.* (2012b) noted that land with *Brassica* and application of 35 days old *Brassica* biomass @ 0.5 -1.0 kg m^{-2} increased yield contributing characters and yield of wheat.

Mirabelli *et al.* (2004) evaluated five cover crops in sub-plots following chick-pea: hairy vetch (*Vicia villosa*), snail medick (*Medicago scutellata*), rapeseed (*Brassica napus* var.*oleifera*), italian ryegrass (*Lolium multiflorum*) and subterranean clover (*Trifolium subterraneum*). They found that cover crops resulted in clear weed suppression in the following potato (on average 66 g m^{-2} of weed DM vs 111 g m^{-2}). In weed-free conditions potato yielded more when following legume cover crops and in N control than when following rapeseed and Italian ryegrass and in no N control (on average 50.6 vs 46.0 t ha^{-1} tuber FM, respectively, $P < 0.05$). Compared to N control, italian ryegrass and snail medick were more weed suppressive in the following tomato (on average 266 g m^{-2} of weed DM vs 409 g m^{-2}, $P < 0.05$). Compared to N control, tomato following these two cover crops had also lower yield reduction in the weed presence for respect to weed-free conditions (on average 15.2 vs 28.6 %, $P < 0.05$). Hairy vetch gave low yield reduction in the weed presence (16.9 %) but did not have relevant weed suppression effect.

Boydston and Hang (1995) evaluated fall-planted rapeseed and sudangrass for weed control in potato during a two-year study. Potato following rapeseed yielded 25% and 17% more total tuber weight than potato following sudangrass in 1992 and fellow in 1993 respectively.

2.1.3 Effect on weed

Rahman *et al.* (2012b) noted that weed population and weed dry weight showed the highest result in fallow land with no biomass application. Fallow land, less matured biomass and no biomass application and their interaction encouraged growth of weed and dry weight of weed that means *Brassica* biomass reduced weed growth in all cases of application. Weed control was quite positive with *Brassica* biomass.

Burton *et al*. (2008) reported that rye (*Secale cereale*) was used as a winter cover crop, often for the allelopathic weed suppression provided by the mulch. Rye produced several allelochemicals, the principle allelochemical group included the benzoxazinone (BX), represented by DIBOA.

Dayan (2008) suggested rotation with sorghum (*Sorghum bicolor* L.) that this species was allelopathic. This phytotoxicity is associated with a group of lipid benzoquinones called sorgoleone that exude from the root hairs of sorghum. Sorgoleone is released directly in the soil and acts like a pre-plant incorporated herbicide. Therefore, the allelopathic effect of sorgoleone strong on young developing plants, which might take up sufficient amount of sorgoleone.

Ashrafi *et al.* (2007) reported that Barley [*Hordeum vulgare* (L.) Koch.] contained water soluble allelochemicals that inhibit the germination and growth of other species. Growth of Wild Barley, as indicated by plant height and weight, was significantly reduced when grown in soil previously cropped to Barley compared with that cropped to Wild Barley. In bioassays, Barley extracts reduced Wild Barley hypocotyl length, hypocotyl weight, radicle weight, seed germination, and radicle length by as much as 44, 57, 61, 68 and 79 %, respectively, when compared with water control. Increasing the water extract concentrations from 4 to 20 g per 100 ml of water of all Barley parts significantly increased the inhibition of Wild Barley germination, seedling length and weight. Based on 8-day-old wild barley radicle length, averaged across all extract concentrations, the degree of toxicity of different Barley plant parts can be ranked in the following order of inhibition: leaves > flowers > mixture of all plant parts > stems > roots.

Bellostas *et al.* (2007) reported that glucosinolates were amino acid derived allelochemicals present in all plants of the order Capparales. Species within the Brassicaceae were found to differ in their glucosinolate profile and glucosinolate concentrations. The glucosinolate profile of corresponding ripe seeds was also determined. The determined glucosinolate profiles were an initial step in assessing the biofumigation potential of these species of the Brassicaceae family.

Gomes *et al.* (2007) reported that intercropping combined with competitive maize cultivars could reduce the use of herbicides to control weeds. The cowpea was inefficient in controlling weed, reducing the maize yields and not producing any grain. The maize cultivars 'BA 8512' and 'BA 9012' showed the highest mean green ear yield, and the highest grain yield in hand-weeded, no-weeded and intercropped split-plots. On the other hand, the maize cultivar 'EX 6004' showed such high means only in no-weeded and intercropped split-plots. 'EX 4001' presented the worst means in these variables for hand-weeded, no-weeded and intercropped split-plots.

Meschede (2007) evaluated seven treatments consisting of the following soil crop covers: Millet ADR 500 (*Penisetum americanum* L.), Millet ADR300, Sorghum (*Sorghum bicolor* L.), Maize (*Zea mays* L.), Crotalaria (*Crotalaria juncea* L.), Castorbean plant (*Ricinus communis* L.) and spontaneous vegetation. Sorghum yielded the highest dry matter weight (11.890 kg ha^{-1}); sorghum, millet and crotalaria showed a better ability to suppress weeds. The spontaneous vegetation presented the lowest biomass values. Maize and Castorbean presented a lower crop cover potential. Biomass accumulation by the covers was inversely proportional to weed biomass.

Norsworthy *et al.* (2007) conducted experiments to compare growth characteristics, biomass production and glucosinolate content of seven autumn-planted glucosinolate-producing cover crops that were terminated the following spring. *D. sanguinalis* control by cover crops ranged from 38% to 79%, and *A. palmeri* control was 23% to 48% at 4 weeks after transplanting (WATP) bell pepper in 2004. *D. sanguinalis* control was positively correlated with total glucosinolate production, but *A. palmeri* control was not. *D. sanguinalis* control in 2005 ranged from 0% to 38% at 2 WATP. In the absence of weeds, cover crops did not negatively affect fruit yields which were often higher than in the absence of a cover crop.

Rudrappa *et al.* (2007) tested the occurrence of root-derived allelopathy in the invasiveness of *P. australis*. The study highlights the persistence of the exuded gallic acid in *P. australis*'s rhizosphere and its inhibitory effects against *A. thaliana* in the soil. Gallic acid demonstrated an inhibitory effect on *Spartina alterniflora*, one of the salt marsh species it successfully invades.

Arlauskiene and Maiksteniene (2006) designed an experiment to identify the effects of legume pre-crops and intercrops as well as the impact of their biomass incorporated as green manure on the weed incidence in succeeding cereals. Under sown intercrops (*Trifolium pratense* L., *Lolium multiflorum* Lam., *Dactylis glomerata* L.), reduced the number of weeds in cereals (on average 13.9%).

During the cereal post-harvest period red clover performed best at suppressing weeds, and its positive effect persisted in the year following incorporation of intercrops biomass.

Xuan *et al.* (2005a) evaluated some higher plants with strong allelopathic properties of alfalfa (*Medicago sativa* L. cv. Rasen) and kava (*Piper methysticum* L.) after soil amendment. Both alfalfa and kava strongly inhibited barnyardgrass and monochoria growth for up to 10 days (80-100 % weed control). After 20-25 days, the magnitude of inhibition was drastically reduced, but was still effective (50 % weed control). Chemicals released from allelopathic plants incorporated into soil are toxic and cause inhibition of certain species and could be exploited as a biological tool for weed management.

Hall *et al.* (2004) experimented hairy vetch (*Vicia villosa* Roth.), fall rye (*Secale cereal* L.), yellow sweet clover (*Melilotus officinalis* L.) and white clover (*Trifolium repens* L.) as cover crops with cauliflower (*Brassica oleracea* L. var. *botrytis*), and compared to monoculture cauliflower. Monoculture and rototilled hairy vetch plots showed the highest number of weeds throughout the experiment. Mowed plots showed the lowest weed densities. None of the experimental treatments tested (rototilled hairy vetch, yellow sweet clover and white clover and mowed white clover) showed significant allelopathic potential. The resultant yields in the plots showed that rototilling of the cover crop prior to planting improved cauliflower yield, compared to mowing. The rototilled plots generally had the most weeds, but presumably the increased nutrient availability and reduced competition from the cover crops resulted in improved cauliflower yields, compared to mowed plots. Mowing of the cover crop decreased weed numbers, but most likely the higher level of competition and lower nutrient availability resulted in smaller cauliflower yields.

Gallandt and Haramoto (2004) reported allelopathic potential had been well documented for cover crops such as cereal rye (*Secale cereale* L.), hairy vetch (*Vicia villosa* Roth) and red clover (*Trifolium pratense* L.). They discussed unique attributes of Brassicas that make them promising options for pest management, as well as generally beneficial cover crops. From controlled settings on the effects of Brassicas, Brassica extracts and isolated compounds contained therein on seed germination, seedling emergence and establishment, and seedling growth effects that, combined or taken alone, could contribute to reducing the density and vigor of weed communities in the field.

Kristiansen *et al.* (2003) tested *Brassica* varieties with high GSL levels (*Brassica juncea* cv. *Fumus* and *Raphanus sativus* cv. *Weedcheck*) in combination with mechanical weed control and another locally grown forage crop (*Lolium multiflorum* cv. *Conquest*) for their effects on weed growth during the pre-crop phase and subsequent weed and lettuce growth during the in-crop phase. Weed control was closely related to the amount of light reduction by the cover crops, while competition for nutrients and water appeared to be less important in weed suppression by the cover crops.

Tawaha and Turk (2003) stated that growth of wild barley, as indicated by plant height and weight, was significantly reduced when grown in soil previously cropped to black mustard compared with that cropped to wild barley. Soil incorporation of fresh black mustard roots and both roots and shoots reduced wild barley germination, plant height and weight when compared with a no-residue control. In bioassays, black mustard extracts reduced wild barley hypocotyl length, hypocotyl weight, radicle weight, seed germination, and radicle length by as much as 44, 55, 57, 63 and 75 %, respectively, when compared with a water control.

Chikoye *et al.* (2001) reported that legume cover crops can suppress weeds more quickly than natural fallow. Using of Mucuna as green manure reduced *Imperata cylindrica* dry weight by over 80% within 1-3 years as compared with control (without use of *Mucuna* green manure).

Smith *et al*. (1999) reported that Canola extract at 0.1% concentration stimulated redroot pigweed shoot growth compared to water. Germination of redroot pigweed was only inhibited by lentil extracts at 1 and 2%. Root growth was reduced by all extracts at 1 and 2% compared to water but was only reduced by lentil extract at 0.1%. Shoot growth was only reduced compared to water by lentil extract at 2% .Green foxtail germination was not suppressed by any of the extracts. Root growth was suppressed by lentil, canola, and oat extracts at 0.1 %. At 1 % and 2% all extracts suppressed root growth. Shoot growth was not affected by any plant extracts at 0.1% and was only suppressed by lentil extract at 1%. Lentil, canola, and barley extracts at 2% suppressed green foxtail shoot growth.

Collantes *et al.* (1999) showed that clipping rye seedling shoots below the coleoptiles increased root and root exudate concentrations of hydroxamic acids, the allelochemicals implicated in allelopathy. Since defoliation increased root exudation of these allelochemicals, it might also increase rye's allelopathic activity, and hence its weed suppression ability in the field.

Jones *et al*. (1998) reported that some crop residues were known to have a chemical (allelopathic) as well as physical effect on the growth of subsequent crops and weeds consisted of plots planted to barley, canola, chickpea, fieldpea, mungbean, sorghum and a fallowed control. Four target weed species were planted following these crops. Barley was found to be the most inhibitory (64% and 47% of the fallow treatment for incorporated residue and surface residue treatments respectively). Fieldpea was found to have a significant stimulatory effect on overall weed dry matter production (127%), on incorporated plots, yet did not affect the survival rate of target weeds.

Smolinska *et al.* (1996) reported that *Brassica* tissues were potentially useful in the control of Aphanomyces root rot of peas (*Pisum sativum*), but identity of the responsible compounds and specific impacts of those compounds on the pathogen's infection potential remain uncertain. *Brassica napus* seed meals and water extracts from these meals were used to determine the effect of glucosinolate hydrolysis products on *Aphanomyces euteiches* f. sp. *pisi. B. napus* meal (Dwarf

Essex) containing glucosinolates and intact myrosinase, the enzyme responsible for glucosinolate hydrolysis, completely inhibited infection by *A. euteiches* f. sp. *pisi* oospores.

Teasdale and Mohler (1993) reported rye cover crop residue to be effective at reducing light transmittance (quality and quantity) and soil temperature which in turn reduced or delayed germination and emergence of certain weed species.

2.2 Effect of Crop biomass

2.2.1 Effect on growth characters

Rahman *et al.* (2012b) stated that land with *Brassica* and application of 35 days old *Brassica* biomass @ 0.5 -1.0 kg m^{-2} increased growth of wheat.

Ramanujam *et al*. (2008) investigated by exposing green gram seeds and seedlings to 0, 1.0, 2.5 and 5% concentrations of the aqueous leaf extract adversely affected germination and seedling growth (length, and biomass of shoot, root and plant) lateral root development and nodulation. Besides nodule number and size, the activity of nitrate reductase was inhibited too.

Basotra *et al.* (2005) tested an aqueous leaf and root/tuber extracts of three important medicinal plant species (e.g., *Bergenia ciliata, Hedychium spicatum* and *Potentilla fulgens*) for their allelopathic effects on germination, radicle and plumule elongation of *Amaranthus caudatus, Eleusine coracana, Fagopyrum esculantum, Phaseolus mungoo, Phaseolus vulgaris* and *Triticum aestivum*. The results revealed that: the allelopathic effects increased with increasing concentration of leachats from 2%, 5% to 10%. The susceptible crops were *Amaranthus caudatus* and *Phaseolus mungoo* whose germination, redicle and plumule growth were reduced significantly under aqueous extracts of all three medicinal species.

Khan *et al.* (2005) investigated the allelopathic potential of aqueous extracts of leaves of *Prosopis juliflora* and *Eucalyptus camaldulensis* and bark of *Acacia nilotica*. The results showed that the germination percentage, seedling length (mm) and biomass yield (mg) plant^{-1} of *Ipomoea* sp., *Asphodelus tenuifolius*, *Brassica campestris* and *Triticum aestivum* were significantly affected by tree extracts as compared to control. Eucalyptus and Acacia had stimulatory effect on germination percentage of *A. tenuifolius*, while *P. juliflora* and *E. camaldulensis* had inhibitory effect on *B. campestris*. All extracts had inhibitory effects on seedling length of *T. aestivum* and *B. campestris*. Treatment means indicated that *P. juliflora* and *E. camaldulensis* are more allelopathic than Acacia. Effect of Acacia on the test species was statistically comparable with control, exhibiting its non-inhibitory role in the test species. Species means indicated that *Ipomoea* sp. and *T. aestivum* were less negatively affected than *B. campestris* and *A. tenuifolius*.

Shiraishi *et al.* (2005) experimented with shamrock oxalis (*Oxalis articulata* Savigny), Bowie's woodsorrel (*Oxalis bowiei* Lindl.), trefoil (*Oxalis brasiliensis* Lodd. ex Knowl. et West.), lucky clover (*Oxalis deppei* Lodd. ex Sweet) and *Oxalis hirta* L. The leachates from *O. articulata*, *O. bowiei*, *O. deppei* and *O. hirta* and the exudates from *O. deppei* caused > 84% inhibition of the radicle elongation of lettuce seedlings, but no effect was observed on the seed germination of lettuce. *O. deppei* significantly reduced the weed population in July. A significant relationship was observed between the weed population and the percentage ground coverage of *Oxalis* spp. In contrast to the weed population, a significant relationship was observed between the weed above-ground biomass and the allelopathic activity of exudates from *Oxalis* spp.

Gawronska *et al.* (2004) reported that wheat and mustard was strongly affected by sunflower allelochemicals. Allelochemicals contained in extracts had negative impact on seedling vigour of both species but mustard growth was almost fully inhibited while wheat, although less vigorously, continues to grow. Moreover, along with increased extract concentration number of roots per wheat seedling increased. At autotrophic growth stage, differences between these two species became less evident but still wheat appears to be more tolerant to allelopathy stress especially in processes related to plant water status.

2.2.2 Effect on yield and yield contributing characters

Rahman *et al.* (2012b) noted that Land with *Brassica* and application of 35 days old *Brassica* biomass @ 0.5 -1.0 kg m^{-2} increased yield contributing characters and yield of wheat.

Naseem *et al.* (2009) tested Allelopathic influence of sunflower plant water extract (1:10 w/v) against wheat under field conditions. Treatments applied were sunflower plant water extract at pre-emergence, at 25 DAS (days after sowing), pre-emergence + 25 DAS, 25+35 DAS, preemergence + 25 + 35 DAS and control. Wheat variety Inqlab-91 was sown on 13th November, 2005. The inhibitory effects of pre-emergence application on germination of wheat remained unaffected at this stage of application. Application of water extract at pre-emergence + 25 DAS, 25 + 35 DAS and pre-emergence + 25 + 35 DAS increased the wheat yield significantly over control except pre-emergence + 25 + 35 DAS.

Cheema *et al*. (2008) investigated that inclusion of allelopathic crops in rotation systems for weed suppression by early post-emergence application of the mixture of sorghum, sunflower, brassica or mulberry water extracts suppressed total weed dry weight by 40 to 75% and enhanced yield of wheat, maize, cotton and rice by 15 to 25%. Combined application of these water extracts reduced the herbicide(s) dose by 50 to 75%. The intercropping of mungbean in maize was effective to control weeds by 55% and was economical in terms of net benefits. Sorghum and berseem in rotation settings decreased weeds by 85%.

Khan *et al.* (2008) noted that aqueous extracts of Eucalyptus (*Eucalyptus camaldulensis L.)* at a concentration of 10, 15 and 20% had inhibitory effect on wheat germination and effect was found significantly higher than control treatment. Fresh and dry weight of seedling was also reduced significantly over control. The inhibitory effects were increased as the extract concentration increased. These findings indicated that wheat sown in fields which had leaf litter of *E. camaldulensis* L. adversely affected regarding germination, growth and ultimately resulting in lower yields of wheat.

Mahmood *et al.* (2008a) explored possibilities of reducing herbicide dose in combination with different allelopathic plant water extracts for weed management in maize by applying Atrazine (Atrazine 38SC) at 0.167 kg a.i. ha^{-1} was tank mixed with 18 L ha^{-1} water extracts each of sorghum + brassica + mulberry, sorghum + brassica + sunflower, sorghum + sunflower + rice, sorghum + sunflower + maize and sorghum + maize + rice as early post-emergence, i.e., 15 days after sowing (DAS). Combination of sorghum + sunflower + brassica each at 18 L ha^{-1} and 1/3 dose of atrazine (0.167 kg ha^{-1}) reduced total weed dry weight by 86 to 75% at 45 DAS respectively. Maize yield increased by 48 to 51 % by the combination treatment of sorghum + sunflower + brassica water extracts each at 18 L ha^{-1} and with 1/3 dose of atrazine (0.167 kg ha^{-1}) as early post emergence (15 DAS) over the control, respectively, and yields were equal to the yields obtained from the recommended rate of S-metolachlor + atrazine and atrazine alone.

Mahmood *et al*. (2008b) evaluated the allelopathic influence of mulches of different plant residues as sorghum (*Sorghum bicolor),* sunflower *(Helianthus annus),* rice *(Oryza sativa)* and maize *(Zea mays)* applied in a combination of three each at 6.0 Mg ha^{-1} as surface application at sowing. The combination of rice + sunflower + maize each at 6.0 Mg ha^{-1} increased maize yield by 54 to 69% as compared to the control and yield was similar to the yield obtained from S-metolachlor + atrazine treatment.

Cheema *et al*. (2003a) revealed that atrazine (150 g a.i. ha^{-1}) in combination with sorgaab (12 L ha^{-1}) gave 39% maize grain yield increase over control while atrazine alone (300 g a.i. ha^{-1}) gave 41% higher yield than control in maize.

Cheema *et al.* (2003b) tested the response of wheat to foliar application of sorghum (*Sorghum bicolor*), sunflower (*Helianthus annuus*) and eucalyptus (*Eucalyptus camaldulensis*) water extracts individually and in combinations with each other at different doses under field conditions. Concentrated sunflower water extract @ 12 L ha-1 sprayed at 30 and 40 days after sowing gave consistently increased wheat yield by 5.5% over control. A combination of water extracts of sorghum, sunflower and eucalyptus each @ 12 L ha^{-1} and 8 L ha^{-1} were also economical.

Barker and Bhowmik (2001) reported that crop residues have many potential uses in cropping systems, among which are imparting weed control. In one experiment, residues were imported to the vegetable plots and applied as surface mulches or incorporated shallowly into the ground. In another experiment, the residues were grown on site as cover crops in the year preceding vegetable production and disked into the plots. Application of imported residues was more effective in weed control and yield enhancement than the cover crop residues. Imported residues were effective in control of early emerging weeds, whereas with the cover crops supplemental weed management was required for early weed control. Weed control did not differ substantially with species of residue, but control increased as amount of incorporated residues increased from 6 to 24 Mg/ha. Weed control with residue incorporation at 6 Mg/ha was as effective as a mulch of 24 Mg/ha. If weed control was imparted by the residues, crop yields with any residue treatment were equivalent to those from plots kept relatively weed-free by tillage. Yields did not vary with amounts of residues applied.

Rippin *et al.* (1994) incorporated plant residues of *Erythrina poeppigiana* trees (10 t/ha dry matter) at 6 by 3 m reduced weed biomass by 52%, while *Gliricidia sepium* trees (12 t/ha dry matter) planted at 6 by 0.5 m reduced weed biomass by 28%, in comparison to controls. *Erythrina* had a considerable impact on grass weeds, while *Gliricidia* reduced the incidence of some dicot weeds. Weed competition significantly reduced maize yield in all systems. Nevertheless weed suppression contributed to the higher maize grain yield under *Erythrina* and *Gliricidia* alley cropping of 3.8 t per hectare as opposed to the unmulched control yield of 2.0 t per hectare.

2.2.3 Effect on weed

Rahman *et al.* (2012b) noted that weed population and weed dry weight showed the highest result in fallow land with no biomass application. Fallow land, less matured biomass and no biomass application and their interaction encouraged growth of weed and dry weight of weed that means *Brassica* biomass reduced weed growth in all cases of application. Weed control was quite positive with *Brassica* biomass.

Odhiambo *et al*. (2010) examined that weed suppression by clovers was affected by site, the growth characteristics of clover species and management practices. On the low productivity site, weed suppression by clovers was greater than on the high–productivity site. Cowpea, *Mucuna*, *Lablab* and sunhemp plots had a significantly lower weed dry matter (5.30, 11.97, 5.83, and 21.03 gm^{-2}, respectively) than the control (49.47 gm^{-2}) The application of green manure species and nitrogen reduced the number of Striga by 100% in the 6 and 12th weeks.

Sisodia and Siddique (2010) conducted a study to investigate the allelopathic effects of *Croton bonplandianum* weed on seed germination and seedling growth of crop plants (*Triticum aestivum* L.,*Brassica oleracea* var. botrytis L. and *Brassica rapa* L.) and weed plants (*Melilotus alba* Medik., *Viciasativa* L. and *Medicago hispida* Gaertn). Aqueous extracts of root, stem and leaf of Croton at 0.5, 1.0, 2.0 and 4.0% concentrations were applied to find out their effect on seed germination and seedling growth of test plants under laboratory conditions. The root, stem and leaf extracts had no effect on seed germination. The stem extracts had a stimulatory effect on the shoot length at all concentration levels, as against an inhibitory effect of leaf extracts. Among the different parts, leaves were the most allelopathic and stems were least allelopathic.

Uremis *et al*. (2009) evaluated the allelopathic potential of residues of some brassica species, which were round white radish (*Raphanus sativus* L.), garden radish (*R. sativus* L.), black radish (*R. sativus* L. var. *niger*), little radish (*R.*

sativus L. var. *radicula*), turnip (*Brassica campestris* L. subsp. *rapa*) and rapeseed (*Brassica napus* L. *oleifera* DC.) on johnsongrass under both laboratory and field conditions. All species suppressed Johnson grass in field and laboratory conditions. The lowest suppression was from garden radish, which had already been used to control johnsongrass by few farmers in Turkey. It was concluded that the plants studied could be used to control johnsongrass. Higher amount of isothiocyanates (isothiocyanate benzyl, Isothiocyanate allyl) in black radish extract and lower amount of isothiocyanates at garden radish extract were determined. Parallel results for johnsongrass suppression and amount of isothiocyanates showed that allelopathy play roles in johnsongrass suppression by brassica species.

Naseem *et al*. (2009) tested Allelopathic influence of sunflower plant water extract (1:10 w/v) against weeds under field conditions. Treatments applied were sunflower plant water extract at pre-emergence, at 25 DAS (days after sowing), pre-emergence + 25 DAS, 25+35 DAS, preemergence + 25 + 35 DAS and control. Wheat variety Inqlab-91 was sown on 13th November, 2005. The inhibitory effects of pre-emergence application on germination of *Phalaris minor* were higher. Application of water extract at pre-emergence + 25 DAS, 25 + 35 DAS and pre-emergence + 25 + 35 DAS suppressed the growth of *Phalaris minor* Retz., *Chenopodium album* L., *Coronopus didymus* L. and *Avena fatua* L. Inhibitory effects were species specific and increased with increasing the water extract application frequency.

Kruidhof *et al.* (2008) reported that weeds, green manures residues have inhibitory affect on germination and establishment of weed green manures that contain a high level of allelochemicals seem well-suited for weed suppression.

Boydston (2008) observed that Brassicaceae cover crops suppressed weeds due to fast emergence and vigorous competitive growth during fall establishment and allelopathic substances released during degradation of the cover crop residues. Early season weed emergence was often suppressed following fall-planted *S. alba* or *B. napus* cover crops. The mechanisms of weed suppression with Brassicaceae cover crops were not completely understood, but breakdown products of glucosinolates, such as isothiocyanates and ionic thiocyanate (SCN) are believed to contribute to weed suppression.

Igbal and Cheema (2008) evaluated crop water extracts (sorghum, sunflower and brassica) @ 12 and 15 L ha^{-1} in different combinations were tank mixed with reduced rates of glyphosate at 67% (767 g a.e. ha^{-1}) of label rate (2.3 kg a.e. ha^{-1}) and sprayed as directed post emergence at 40 days after sowing (DAS). Purple nutsedge density was decreased by 59-99% and dry weight by 66-99% as compared to control. The high rate of crop water extracts (15 L ha^{-1}) significantly reduced the growth of purple nutsedge more than the lower rates (12 L ha^{-1}). Seed cotton yield in these treatments was comparable to herbicide applied at recommended rates.

Mahmood *et al.* (2008a) explored possibilities of reducing herbicide dose in combination with different allelopathic plant water extracts for weed management in maize by applying Atrazine (Atrazine 38SC) at 0.167 kg a.i. ha^{-1} was tank mixed with 18 L ha^{-1} water extracts each of sorghum + brassica + mulberry, sorghum + brassica + sunflower, sorghum + sunflower + rice, sorghum + sunflower + maize and sorghum + maize + rice as early post-emergence, i.e., 15 days after sowing (DAS). Weed species present in the experimental area were *Trianthema portulacastrum, Cyprus rotundus, Dactyloctenium aegyptium, Cynodon dactylon* and *Cleome viscosa.* Combination of sorghum + sunflower + brassica each at 18 L ha^{-1} and 1/3 dose of atrazine (0.167 kg ha^{-1}) reduced total weed dry weight by 86 to 75% at 45 DAS respectively.

Mahmood *et al*. (2008b) evaluated the allelopathic influence of mulches of different plant residues as sorghum (*Sorghum bicolor),* sunflower *(Helianthus annus),* rice *(Oryza sativa)* and maize *(Zea mays)* applied in a combination of three each at 6.0 Mg ha^{-1} as surface application at sowing. Combination of rice +

sunflower + maize each at 6.0 Mg ha^{-1} was relatively better in reducing the total weed dry weight by 70 to 85% and was followed by treatment combination of sorghum + sunflower + maize each at 6.0 Mg ha^{-1} with 58 to 81% reduction.

Rehman *et al*. (2008) investigated the effect of plant population (0.20, 0.25 and 0.30 million plants ha^{-1}) against sorghum, sunflower and rice water extracts each at 15 and 18 L ha^{-1} (20, 40 and 60 DAT) and a post-emergence herbicide Nominee (bispyribac-sodium 100 SC) at 21 g a.i. ha^{-1} 20 days after transplanting (DAT), on weeds in rice. On an average, 45% and 52% reduction in total weed dry weight during three years of experimentation was recorded at 75 DAT. Foliar spray of allelopathic extract mixtures at 15 and 18 L significantly suppressed (46 to 61%) total weed dry matter production.

Maharjan *et al.* (2007) studied allelopathic effects of aqueous extract of leaves of *Parthenium hysterophorus* on seed germination and seedling growth of three cereal crops (*Oryza sativa* L., *Zea mays* L. and *Triticum aestivum* L.), three cultivated crucifers (*Raphanus sativus* L., *Brassica campestris* L. and *Brassica oleracea* L.) and two wild species of family Asteraceae [*Artemisia dubia* Wall ex. Besser and *Ageratina adenophora* (Spreng) King and HE Robins]. Leaves of *Parthenium hysterophorus* might be a source of natural weedicide against *Ageratina adenophora* to control invasive plants.

Kumar *et al.* (2007) tested aqueous leaf of two dominant weeds (*Eupatorium odoratum* and *Ageratum conyzoides*) for their allelopathic influences on germination and radicle extension of test crops (*Oryza sativa, Brassica campestris* and *Glycine max*). The germination and radicle extension of *B. campestris* was completely inhibited by *E. odoratum* and *A. conyzoides*. The germination of *G. max* was inhibited (8.04%) under *E. odoratum* and stimulated (14.94%) under *A. conyzoides* compared with control. The germination of *O. sativa* was not affected by any of the two weeds studied; however, the radicle growth was inhibited to the extent of 41.68% and 17.02% under *E. odoratum* and *A. conyzoides*, respectively, compared with control. The radicle growth of *G. max* was also inhibited by

10.71% under *E. odoratum* and stimulated by 3.96% under *A. conyzoides*. *E. odoratum* was found more toxic weed for the selected test crops.

Javaid *et al.* (2006) evaluated herbicidal effects of aqueous root and shoot extracts of three allelopathic crops, viz. sunflower (*Helianthus annuus* L.), sorghum (*Sorghum bicolor* L.) and rice (*Oryza sativa* L.) against germination and growth of the noxious alien weed *Parthenium hysterophorus* L. The study indicated insignificant effects on shoot length and seedling biomass while germination and root length were significantly reduced by extracts of all the test crops. In a foliar spray bioassay, aqueous shoot extracts of 50 and 100% w/v (on a fresh weight basis) of sunflower and sorghum were applied to 10 day old *Parthenium* plants. The root biomass of *Parthenium* plants was significantly suppressed by 50 and 100% extracts of both the test allelopathic extracts. Both concentrations of sorghum extracts significantly reduced shoot biomass, but sunflower extract was effective only at the lower concentration.

Xuan *et al.* (2005b) found that incorporation of the allelopathic plants to rice fields at 1-5 days after transplanting gave the greatest weed reduction. The selective impacts of these plants on major noxious paddy weeds (such as *Echinochloa crus-galli, Monochoria vaginalis, Rotala indica, Eleocharis acicularis, Scirpus juncoides, Doparium juncencum, Lindernia pyxidaria,* and *Cyperus difformis*) were demonstrated. Some species (*Alpinia zerumbet, Ageratum conyzoides, Azadirachta indica, Piper methysticum, Leucaena leucocephala,* and *Melia azedarach*) showed strong inhibition on major plant pathogens (such as *Corticium rolfsii, Fusarium solani, Pyricularia grisea, Pythium spp., Rhizopus stolonifer, Taphrina deformans*, and *Thanatephorus* cucumeris) and they might become effective tools in reducing plant pathogens and weeds. Numerous growth inhibitors (alkaloids, phenolics, fatty acids, lactones, and flavonoids) identified from these allelopathic plants were responsible for their allelopathic properties.

Severino and Christoffoleti (2004) designed a field experiment to determine the effect of the green manure species *Crotalaria juncea*, *Arachis pintoi* and pigeon pea on the weeds *Brachiaria decumbens*, guineagrass and hairy beggarticks, and on the natural weed infestation in the inter rows area of an avocado orchard. The weed species were suppressed differently by each green manure species. When the green manure was incorporated into the top 5 cm of soil or left on the surface, in a greenhouse experiment, the emergence of weed seeds was significantly inhibited, depending on the species, and on the amount and depth of green manure incorporation.

Riley *et al*. (2004) reported that mulching vegetables with chopped plant material both supplies nutrients and suppress weeds. Highly significant yield effects were found in both vegetable crops. Relative to the control treatment, beet yields were 135% and 123% after mulching, with and without hand-weeding, respectively, whilst cabbage yields were 124% and 118%. Yields after inter-row harrowing were 79% for beet and 83% for cabbage, relative to hand-weeding. Weed control on mulched plots was satisfactory throughout the growing season, probably due to the slow decay of the grass. This study showed that chopped plant material prevents weed growth as well as supplying nutrients.

Mansoor *et al.* (2004) designed an experiment to investigate the efficacy of various weed management strategies in mungbean. Water extracts of sorghum, Eucalyptus and Acacia were used in comparison with hand weeding and pre-emergence herbicide. All the treatments significantly affected number of branches/plant, number of pods/plant, 1000 grain weight and grain yield. Application of water extract of Acacia ranked at the top in yield and almost all the yield components followed by two hand weeding + Pre-emergence herbicide treatments.

Oueslati (2003) examined the allelopathic effect of diluted extracts of roots, leaves and stems of twodurum wheat varieties viz., Karim and Om rabii on barley (variety Manel) and bread wheat (variety Ariana). Minimum weeds were found when diluted extracts was used in the experiment.

Norsworthy (2003) evaluated the allelopathic potential of wild radish in controlled environments. Germination and radical growth of all species were reduced by the extract compared with distilled water. However, topical applications of the aqueous extract failed to induce injury on any species by 7 d after treatment. Emergence and shoot fresh weight of the bioassay plants were reduced by wild radish residue incorporated into soil, with the level of suppression dependent on the quantity of residue incorporated. Sickle pod and prickly sida were extremely sensitive to incorporated wild radish residues, with > 95% fresh weight reduction at 0.5% (wt/wt) residue, compared with an untreated control. Conversely, yellow nutsedge showed a high degree of tolerance in all trials. Of the crops evaluated, cotton emergence and growth were most sensitive to incorporated wild radish residues.

Tawaha and Turk (2003) observed that soil incorporation of fresh black mustard roots and both roots and shoots reduced wild barley germination, plant height and weight when compared with a no-residue control. In bioassays, black mustard extracts reduced wild barley hypocotyl length, hypocotyl weight, radicle weight, seed germination, and radicle length by as much as 44, 55, 57, 63 and 75 %, respectively, when compared with a water control. Increasing the water extract concentrations from 4 to 20 g per 100 ml of water of all black mustard parts significantly increased the inhibition of wild barley germination, seedling length and weight. They also reported that black mustard (*Brassica nigra* L.) contained water-soluble substances that inhibited the germination and seedling growth of wild oat (*Avena fatua* L.). Aqueous extracts of *B. nigra* leaf, stem, flower and root plant part were made to determine their effects on germination and dry weights of hypocotyl and radicle length of 8-d old *A. fatua* L. seedlings over a range of extract concentrations. Increasing the aqueous extract concentrations of separated *B. nigra* L., plant parts significantly inhibited *A. fatua* L. germination, seedling length and weight. Radicle length was more sensitive to extract source than seed germination or hypocotyl length. Soil incorporation of fresh *B. nigra* roots only or both roots and shoots reduced *A. fatua* emergence, plant height, and dry weight per plant.

Cheema *et al.* (2003b) tested the response of wheat weeds to foliar application of sorghum (*Sorghum bicolor*), sunflower (*Helianthus annuus*) and eucalyptus (*Eucalyptus camaldulensis*) water extracts individually and in combinations with each other at different doses under field conditions. Concentrated sunflower water extract @ 12 L ha-1 sprayed at 30 and 40 days after sowing gave consistently better weed control. A combination of water extracts of sorghum, sunflower and eucalyptus each @ 12 L ha^{-1} and 8 L ha^{-1} were also economical. However, conventional methods like hand weeding and herbicides, though effective in weed control, were uneconomical due to higher costs.

Penfold (2003) investigated the capacity for a range of cover crops to compete with weeds, and a variety of mulching materials to inhibit weed germination and growth in the undervine area. Wheat straw was the most effective inhibitor of weeds. Compost based mulches inhibited the growth of most weeds, but if seed rain from the mid-row occurred, they also presented a very desirable growing medium for weeds.

Om *et al*. (2002) listed the allelopathic effect of different weeds on *Phalaris minor*. It is clear from the data that the allelopathic potentiality was in the following order: C*henopodium album* L.< *Medicago denticulate* L.< *Melilotus indica* L.< *Convolvulus arvensis* L. (inhibiting 100% germination over control) < *Vicia hirsute* L. (inhibited 86.33% germination) < *Cirsium arvense* L. (47.85% inhibition) < *Lathyrus aphaca* L. (37.98%) < *Rumex acetosella* L. (9.36%). Two weeds, i.e. one grassy (*Cynodon dactylon* L.) and one broad leaf (*Coronopus* didymus L.) had stimulating effect by 7.85 and 3.30 per cent increase in germination. The length of radicle and plumule was affected in the similar order as that of germination. Higher concentration of weed extract (1:4) had more inhibiting effect by about 20 to that of lower concentration (1:8).

Brandsaeter and Riley (2002) showed that the winter annual legume Hairy Vetch (*Vicia villosa* Roth.) and the biennial legume Yellow Sweet Clover {*Melilotus officinalis* (L.) Pall.} were probably the most promising species. Preliminary results, from experiments in which cauliflower was transplanted into a mulch of mown Hairy Vetch, showed that the green manure effect of this species was better when incorporated into the soil than when used as surface mulch. The use of clover/grass material as a surface mulch in carrots, red beet and white cabbage has given good control of annual weeds, but not of perennials. It is difficult to quantify the amount of clover material needed for sufficient weed control in different vegetables. However, 6, 9 and 12 tonnes DM ha^{-1} for white cabbage, red beet and carrots, respectively. From a holistic point of view; the use of clover material has also given promising control of pests, especially in carrots, as well as having substantial nutritional value when used as either green manure or mulch.

Xuan and Tsuzuki (2001) reported that Alfalfa (*Medicago sativa* L.) contained allelopathic chemicals that inhibit the growth of weeds. The results indicated that alfalfa pellet significantly inhibited germination and growth of 4 weed species, viz., *Echinochloa orygicola, Digitaria ciliaris, Cyperus difformis and Monocholia vaginalis* in rice paddies. Among the 4 tested weeds, the maximum inhibitory effect of alfalfa pellet was seen against *Cyperus difformis*. The degree of inhibition of weed growth by alfalfa pellet became stronger as the application of concentration increased.

Ata and Jamil (2001) reported that the water extracts of many crops e.g. sorghum, sunflower, Brassica, sesame, eucalyptus, tobacco etc, contain a number of allelochemicals which were more effective and economical to control the weeds of many crops. In mature sorghum plants nine water soluble allelochemicals have been identified which were phytotoxic to the growth of certain weeds.

Petersen *et al.* (2001) evaluated the allelopathic potential of isothiocyanates (ITC) released by turnip–rape mulch [*Brassica rapa* (Rapifera Group)–*Brassica napus* L.]. They found that Isothiocyanates were strong suppressants of germination on tested species spiny sowthistle [*Sonchus asper* (L.) Hill], scentless mayweed (*Matricaria inodora* L.), smooth pigweed (*Amaranthus hybridus* L.), barnyard grass [*Echinochloa crusgalli* (L.) Beauv.], blackgrass (*Alopecurus myosuroides* Huds.) and wheat (*Triticum aestivum* L.) and probably interact with weed seeds in the soil solution and as vapor in soil pores.

Ohno *et al.* (2000) reported that there was a 20% reduction of radicle growth in the green manure treatment in comparison with the wheat stubble treatment, but only at the first sample date after residue incorporation (8 DAI). The radicle growth reduction had the highest correlation with the concentration of soluble phenolics in the soil: water extracts. The close agreement of the predicted and observed root growth reduction at 8 DAI further supports clover residue as the source of the phytotoxicity. Their study demonstrates that the potential exists for using legume green manures to reduce the amounts of synthetic herbicides needed for weed control.

Chandra Babu and Kandasamy (1997) evaluated allelopathic potential of *Eucalyptus globulus* Labill. (gum tree) where fresh and dried leaf leachates was studied using two perennial weeds, viz. purple nutsedge (*Cyperus rotundus* L.) and bermuda grass (*Cynodon dactylon* L. Pers) as test weeds. Aqueous leachate of fresh leaves of eucalyptus significantly suppressed the establishment of vegetative propagules and early seedling growth of the weeds. Leachate of fresh leaf cuttings had growth inhibitory effect on Bermuda grass but showed growth promotion effect on purple nutsedge. Similarly the leachate of dried leaves of eucalyptus had differential influence on the growth of the two weeds. There was a possibility to harness the allelochemicals of eucalyptus leaves as herbicides for the management of these perennial weeds.

Cheema *et al.* (1997) reported that use of foliar sprays of different allelopathic water extracts for inhibiting weeds in field crops reduced weed biomass by 33-53% and increased in wheat yield (7-14%) by application of sorghum (*Sorghum bicolor*) and sunflower (*Helianthus annuus*) water extracts.

Dabney *et al.* (1996) reported that in addition to allelopathic effects, crop residues can exert an effect on weed germination and establishment through other mechanisms. They include delayed nutrient release from decomposing residues, high osmotic potentials close to decomposing residue, and increased incidence of disease following particular crops.

Creamer *et al.* (1996) demonstrated that allelochemicals could be leached from rye shoot residue and used as a control to separate the physical effects of weed suppression of surface rye mulch from other types of interference. Leached rye inhibited emergence of eastern black nightshade (*Solanum ptycanthum* Dun.) by 98%.

Guenzi and McCalla (1966) found phytotoxicity of phenolic acids, particularly p-coumaric acid, from residues of wheat and other cereals.

Moyer and Huan (1996) observed that extracts of lentil (*Lens culinaris* Medic), oat (*Avena sativa* L.), canola (*Brassica napus* L.), and barley (*Hordeum vulgare* L.) were more toxic to flixweed (*Descurainia sophia* L. Webb), stinkweed (*Thlaspi arvense* L.), and downy brome (*Bromus tectorum* L.) than extract of canola was to wheat. The greater toxicity of these crop residues to flixweed, stinkweed and downy brome than to wheat might permit selective management of these weeds in wheat. Flixweed, stinkweed and downy brome are major winter annual weeds in winter wheat and usually required late fall or early spring herbicide treatments in no-tillage systems. Therefore, residues of canola, lentil, oat and barley had potential for reducing herbicide use in winter wheat production and in no-tillage direct seeding farming systems. Crop extracts were not toxic enough to affect the growth in the field of seven other weeds.

Boydston and Hang (1995) evaluated fall-planted rapeseed and sudangrass for weed control in potato during a two-year study. Rapeseed incorporated in the spring in a loamy sand soil reduced weed density 85% and 73% in 1992 and 1993, respectively, and reduced weed biomass 96% and 50% in 1992 and 1993, respectively. Similarly, white mustard tissue added at 20g fresh per 400g dry soil reduced biomass of hairy nightshade and green foxtail by 83% and 70%, respectively.

Masiunas *et al.* (1995) reported that weed suppression by rye residue comes from the considerable biomass rye accumulates early in the growing season, which provides a physical barrier as well as a chemical barrier against weed germination and growth. This suppression extends from 4 to 10 weeks.

Rippin *et al.* (1994) incorporated plant residues of *Erythrina poeppigiana* trees (10 t/ha dry matter) at 6 by 3 m reduced weed biomass by 52%, while *Gliricidia sepium* trees (12 t/ha dry matter) planted at 6 by 0.5 m reduced weed biomass by 28%, in comparison to controls. *Erythrina* had a considerable impact on grass weeds, while *Gliricidia* reduced the incidence of some dicot weeds.

Perez and Ormeno(1991) studied the effects of rye root exudates on wild oats (*Avena fatua* L.). They stated that while hydroxamic acids (e.g., DIBOA and BOA) had demonstrated allelopathic effects, the ability of a plant to exude them as a defensive response had not been shown. GC and HPLC analysis of roots and root exudates of rye cultivars with high hydroxamic acid levels in their leaves, demonstrated the presence of these compounds in their roots and root exudates. They identified the ability of rye (cultivar 'Forrajero-Baer') to reduce wild oat biomass by 84% and 86% compared to wheat and forage oats, respectively.

2.3 Allelopathic effect of concentration of crop biomass

2.3.1 Effect on growth characters

Maharjan *et al.* (2007) observed that water extract from *Hemistepta lyrata* strongly inhibited the germination and seedling growth of wheat (*Triticum aestivum*), rape (*Brassica campestris*), and radish *(Raphanus sativus*), but only slightly inhibited those of sorghum (*Sorghum vulgare*) and cucumber (*Cucumis sativus*). The extract stimulated the growth of roots and hypocotyls at lower concentrations, while it inhibited their growth at higher concentrations.

Khan *et al.* (2008) noted that aqueous extracts of Eucalyptus (*Eucalyptus camaldulensis L.)* at a concentration of 10, 15 and 20% had inhibitory effect on wheat germination and effect was found significantly higher than control treatment. Fresh and dry weight of seedling was also reduced significantly over control. The inhibitory effects were increased as the extract concentration increased.

Cheema *et al.* (2003b) tested the response of wheat and its weeds to foliar application of sorghum (*Sorghum bicolor*), sunflower (*Helianthus annuus*) and eucalyptus (*Eucalyptus camaldulensis*) water extracts individually and in combinations with each other at different doses under field conditions. Concentrated sunflower water extract @ 12 L ha-1 sprayed at 30 and 40 days after sowing gave consistently better weed control and increased wheat yield by 5.5% over control. A combination of water extracts of sorghum, sunflower and eucalyptus each @ 12 L ha^{-1} and 8 L ha^{-1} were also economical. However, conventional methods like hand weeding and herbicides, though effective in weed control, were uneconomical due to higher costs.*In vivo* studies were conducted to asses the allelopathic effects of *eucalyptus* leaf, bark and root extracts at different concentrations (1.0 to 10.0 per cent) on germination and seedling growth of cucumber. Germination and seedling growth were severely hampered by leaf extract than bark and root. Whereas increase in concentration from 1 to 10 per cent there was decrease in germination percentage and seedling growth (Alloli and Narayanreddy, 2000).

Moyer and Haung (1993) noticed that crop extract also reduce germination and growth of other crops. Wheat germination was reduced by lentil, oat, and canola extracts at 4%. Wheat root growth was suppressed by all plant extracts except wheat at 1 %. None of the extracts inhibited shoot growth at 1 %. At 2% extracts of lentil, oat, and canola inhibited wheat shoot growth, and at 4% all plant extracts inhibited shoot growth.

An experiment was conducted by Iqbal and Cheema (2008) where crop water extracts (sorghum, sunflower and brassica) @ 12 and 15 L ha^{-1} in different combinations were tank mixed with reduced rates of glyphosate at 67% (767 g a.e. ha^{-1}) of label rate (2.3 kg a.e. ha^{-1}) and sprayed as directed post emergence at 40 days after sowing (DAS). It was observed that purple nutsedge density was decreased by 59-99% and dry weight by 66-99% as compared to control. The high rate of crop water extracts (15 L ha^{-1}) significantly reduced the growth of purple nutsedge more than the lower rates (12 L ha^{-1}). Seed cotton yield in these treatments was comparable to herbicide applied at recommended rates.

At equal concentration tuber residues reduced the dry weight of corn and soybeans more than foliage residues. As the concentration increased growth decreased, and the effect was more in corn (Drost and Doll, 1980). Both concentrations of sorghum extracts significantly reduced shoot biomass, but sunflower extract was effective only at the lower concentration. Experiments were conducted to investigate allelopathic effect of 1 to 10 per cent aqueous leaf extract on germination and seedling growth in sunflower and sorghum. Results indicated that the germination of both species decreased with increase in extract concentration and with 10 per cent extract concentration the germination was 35 and 20 per cent in sunflower and sorghum respectively. Shoot and root length and dry weight were also decreased by increasing concentration (Murthy *et al*. 1995).

Basotra *et al.* (2005) tested an aqueous leaf and root/tuber extracts of three important medicinal plant species (e.g., *Bergenia ciliata, Hedychium spicatum* and *Potentilla fulgens*) for their allelopathic effects on germination, radicle and plumule elongation of *Amaranthus caudatus, Eleusine coracana, Fagopyrum esculantum, Phaseolus mungoo, Phaseolus vulgaris* and *Triticum aestivum*. The results revealed that: the allelopathic effects increased with increasing concentration of leachats from 2%, 5% to 10%. The susceptible crops were *Amaranthus caudatus* and *Phaseolus mungoo* whose germination, redicle and plumule growth were reduced significantly under aqueous extracts of all three medicinal species.

Gawronska *et al.* (2004) reported that wheat and mustard was strongly affected by sunflower allelochemicals. Allelochemicals contained in extracts had negative impact on seedling vigour of both species but mustard growth was almost fully inhibited while wheat, although less vigorously, continues to grow. Moreover, along with increased extract concentration number of roots per wheat seedling increased. At autotrophic growth stage, differences between these two species became less evident but still wheat appears to be more tolerant to allelopathy stress especially in processes related to plant water status.

2.3.2 Effect on yield and yield contributing characters

Khan *et al.* (2008) indicated that wheat sown in fields which had leaf litter of *E. camaldulensis* L. adversely affected regarding germination, growth and ultimately resulting in lower yields of wheat. Ashrafi *et al.* (2007) reported that based on 8-day-old wild barley radicle length, averaged across all extract concentrations, the degree of toxicity of different Barley plant parts can be ranked in the following order of inhibition: leaves > flowers > mixture of all plant parts > stems > roots. Cheema *et al.* (2003a) revealed that atrazine (150 g a.i. ha^{-1}) in combination with sorgaab (12 L ha^{-1}) gave 39% maize grain yield increase over control while atrazine alone (300 g a.i. ha^{-1}) gave 41% higher yield than control in maize.

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Khan *et al.* (2008) noted that aqueous extracts of Eucalyptus (*Eucalyptus camaldulensis L.)* at a concentration of 10, 15 and 20% had inhibitory effect on wheat germination and effect was found significantly higher than control treatment. Fresh and dry weight of seedling was also reduced significantly over control. The inhibitory effects were increased as the extract concentration increased. These findings indicated that wheat sown in fields which had leaf litter of *E. camaldulensis* L. adversely affected regarding germination, growth and ultimately resulting in lower yields of wheat.

Ramanujam *et al*. (2008) investigated by exposing green gram seeds and seedlings to 0, 1.0, 2.5 and 5% concentrations of the aqueous leaf extract adversely affected germination and seedling growth (length, and biomass of shoot, root and plant) lateral root development and nodulation. Besides nodule number and size, the activity of nitrate reductase was inhibited too.

Norsworthy (2003) evaluated the allelopathic potential of wild radish in controlled environments. Germination and radical growth of all species were reduced by the extract compared with distilled water. However, topical applications of the aqueous extract failed to induce injury on any species by 7 d after treatment. Emergence and shoot fresh weight of the bioassay plants were reduced by wild radish residue incorporated into soil, with the level of suppression dependent on the quantity of residue incorporated. Sickle pod and prickly sida were extremely sensitive to incorporated wild radish residues, with > 95% fresh weight reduction at 0.5% (wt/wt) residue, compared with an untreated control. Conversely, yellow nutsedge showed a high degree of tolerance in all trials. Of the crops evaluated, cotton emergence and growth were most sensitive to incorporated wild radish residues.

2.3.3 Effect on weed

Jayakumar (1995) studied allelopathic effects of *Cassia serecia* on *Parthenium* and reported that aqueous extracts of different plant organs of *Cassia sericea* viz, root, stem, pod wall and leaf inhibited seed germination and seedling vigour of *Parthenium*.Inhibition was statistically significant over control at higher concentration of aqueous extract (undiluted 1:10) than at lower concentration. Adkins and Sowerby (1996) observed that aqueous leachates of *Parthenium* weed leaves on the germination and seedling growth of five test species. Germination of climbing buckwheat (*Polygonum convolvulus*), liver seed grass (*Urochloa pannicoides*), buffel grass (*Cenchurus ciliaris*) and *Parthenium* weed were significantly (P< 0.05) depressed (92,95,98 and 80 per cent respectively) at highest leachates concentration used (250 mg fresh leaf material / ml). While, lowest concentration (50 mg fresh leaf material / ml) significantly (P< 0.05) depressed climbing buckwheat, liver seed grass and buffel grass (80, 80 and 87 per cent respectively) but not *Parthenium* weed. Tripathi and Viashya (1997) observed that the aqueous extracts (0, 10, 20, 30 and 40 per cent) of weeds (*Pluchea lanceolata*, *Imperata cylindrica* and *Parthenium hysterophorus*) on test weed species (*Phylaris minor* and *Echinochloa colonum*) in Petriplate bioassays.

The 40% extracts of *Pluchea lanceolata* and *Imperata cylindrica* reduced germination of *Phylaris minor* by 30 and 35 % respectively. While, 30 % extract *Parthenium hysterophorus* completely inhibited (100.0%) germination of *Phylaris minor*. On the other hand 10 % extracts of *Pluchea lanceolata* and *Imperata cylindrica* caused 40 % inhibition in *Echinochloa colonum.* The extracts of *Parthenium* proved most inhibitory and caused complete inhibition at 40% concentration. Phawa *et al.* (2000) reported that the allelopathic effects of *Parthenium hysterophorus* on *Cyperus rotundus* and three species of *Echinochloa* i.e. *Echinochloa colonum, E. crusgalli, E. glaberscence. Parthenium hysterophorus* extracts at 5, 10 and 15% (w/v) as preemergence and post emergence at 30 days after sowing and even soil drenching with 15, 30 and 45 % solution of Parthenium extract did not cause any allelopathic effects on the growth of any of weeds.

Sinha and Singh (2004) revealed that germination inhibition and growth of *Parthenium hysterophorus* was found restricted by 25 % leaf extract of *Xanthium stromanium.* A significant reduction was also recorded in root/shoot length, seedling vigour and vigour index of Parthenium by leaf extract treatment of *Xanthium stromanium*. The aqueous extracts from fresh and dry leaves of *Lantana camera* inhibited the growth of water hyacinth and killed the plant within six days because of salicylic acid which is major allelochmicals in lantana (Zhung *et al*., 2005).

Smith *et al.* (1999) reported that Canola extract at 0.1% concentration stimulated redroot pigweed shoot growth compared to water. Germination of redroot pigweed was only inhibited by lentil extracts at 1 and 2%. Root growth was reduced by all extracts at 1 and 2% compared to water but was only reduced by lentil extract at 0.1%. Shoot growth was only reduced compared to water by lentil extract at 2% .Green foxtail germination was not suppressed by any of the extracts. Root growth was suppressed by lentil, canola, and oat extracts at 0.1 %. At 1 % and 2% all extracts suppressed root growth. Shoot growth was not affected by any plant extracts at 0.1% and was only suppressed by lentil extract at 1%. Lentil, canola, and barley extracts at 2% suppressed green foxtail shoot growth.

Xuan and Tsuzuki (2001) reported that Alfalfa (*Medicago sativa* L.) contained allelopathic chemicals that inhibit the growth of weeds. The results indicated that alfalfa pellet significantly inhibited germination and growth of 4 weed species, viz., *Echinochloa orygicola, Digitaria ciliaris, Cyperus difformis and Monocholia vaginalis* in rice paddies. Among the 4 tested weeds, the maximum inhibitory effect of alfalfa pellet was seen against *Cyperus difformis*. The degree of inhibition of weed growth by alfalfa pellet became stronger as the application of concentration increased.

Moyer and Haung (1993) conducted an experiment to observe the effect of crop residue on germination and growth of weeds. They found all weed species inhibited both seed germination and seedling growth when they used aquas extract of six different crop residue which were Canola (*Brassica napus* L.), Rye (*Secale cereale* L.), Barley (*Hordeum vulgare* L.), Oats (Avena sativa L.), Indian Head lentil (*Lens culinaris* Medic), and Wheat (*Triticum aestivum* L.)

Dongre *et al*. (2004) studied two black gram varieties that were treated with different concentration of aqueous leaf leachates of eight dominant weeds (*Ageratum conyzoides, Anagelis arvensis, Eclipta alba, Lippia nodiflora, Parthenium hysterophorus, Phylanthus niruri, Pluchea lanceolata* and *Polygonumm plebejum)* to asses their allelopathic effects on seed germination. Leachates of all weed species inhibited both seed germination and seedling growth of both test varieties at 10 per cent concentration. Increase in concentration of leachates was invariably associated with decrease in germination of test cultivars irrespective of weed species.

Green house experiments were conducted to study the effect of yellow nutsedge (*Cyperus rotundus*) plant residues on the growth of corn and soybean. Javaid *et al.* (2006) evaluated herbicidal effects of aqueous root and shoot extracts of three allelopathic crops, viz. sunflower (*Helianthus annuus* L.), sorghum (*Sorghum* *bicolor* L.) and rice (*Oryza sativa* L.) against germination and growth of the noxious alien weed *Parthenium hysterophorus* L. The study indicated insignificant effects on shoot length and seedling biomass while germination and root length were significantly reduced by extracts of all the test crops. In a foliar spray bioassay, aqueous shoot extracts of 50 and 100% w/v (on a fresh weight basis) of sunflower and sorghum were applied to 10 day old *Parthenium* plants. The root biomass of *Parthenium* plants was significantly suppressed by 50 and 100% extracts of both the test allelopathic extracts.

Rippin *et al.* (1994) incorporated plant residues of *Erythrina poeppigiana* trees (10 t/ha dry matter) at 6 by 3 m reduced weed biomass by 52%, while *Gliricidia sepium* trees (12 t/ha dry matter) planted at 6 by 0.5 m reduced weed biomass by 28%, in comparison to controls. *Erythrina* had a considerable impact on grass weeds, while *Gliricidia* reduced the incidence of some dicot weeds. Weed competition significantly reduced maize yield in all systems. Nevertheless weed suppression contributed to the higher maize grain yield under *Erythrina* and *Gliricidia* alley cropping of 3.8 t per hectare as opposed to the unmulched control yield of 2.0 t per hectare.

Mahmood *et al.* (2008a) explored possibilities of reducing herbicide dose in combination with different allelopathic plant water extracts for weed management in maize by applying Atrazine (Atrazine 38SC) at 0.167 kg a.i. ha^{-1} was tank mixed with 18 L ha^{-1} water extracts each of sorghum + brassica + mulberry, sorghum + brassica + sunflower, sorghum + sunflower + rice, sorghum + sunflower + maize and sorghum + maize + rice as early post-emergence, i.e., 15 days after sowing (DAS). Weed species present in the experimental area were *Trianthema portulacastrum, Cyprus rotundus, Dactyloctenium aegyptium, Cynodon dactylon* and *Cleome viscosa.* Combination of sorghum + sunflower + brassica each at 18 L ha^{-1} and 1/3 dose of atrazine (0.167 kg ha^{-1}) reduced total weed dry weight by 86 to 75% at 45 DAS respectively. Maize yield increased by 48 to 51 % by the combination treatment of sorghum + sunflower + brassica water extracts each at 18 L ha^{-1} and with

1/3 dose of atrazine (0.167 kg ha^{-1}) as early post emergence (15 DAS) over the control, respectively, and yields were equal to the yields obtained from the recommended rate of S-metolachlor + atrazine and atrazine alone.

Rehman *et al.* (2008) investigated the effect of plant population (0.20, 0.25 and 0.30 million plants ha^{-1}) against sorghum, sunflower and rice water extracts each at 15 and 18 L ha^{-1} (20, 40 and 60 DAT) and a post-emergence herbicide Nominee (bispyribac-sodium 100 SC) at 21 g a.i. ha^{-1} 20 days after transplanting (DAT), on weeds in rice. On an average, 45 and 52% reduction in total weed dry weight during three years of experimentation was recorded at 75 DAT. Foliar spray of allelopathic extract mixtures at 15 and 18 L significantly suppressed (46 to 61%) total weed dry matter production.

Ohno *et al.* (2000) reported that there was a 20% reduction of radicle growth in the green manure treatment in comparison with the wheat stubble treatment, but only at the first sample date after residue incorporation (8 DAI). The radicle growth reduction had the highest correlation with the concentration of soluble phenolics in the soil: water extracts. The close agreement of the predicted and observed root growth reduction at 8 DAI further supports clover residue as the source of the phytotoxicity. Their study demonstrates that the potential exists for using legume green manures to reduce the amounts of synthetic herbicides needed for weed control.

Brandsaeter and Riley (2002) showed that the winter annual legume Hairy Vetch (*Vicia villosa* Roth.) and the biennial legume Yellow Sweet Clover {*Melilotus officinalis* (L.) Pall.} were probably the most promising species. Preliminary results, from experiments in which cauliflower was transplanted into a mulch of mown Hairy Vetch, showed that the green manure effect of this species was better when incorporated into the soil than when used as surface mulch. The use of clover/grass material as a surface mulch in carrots, red beet and white cabbage has given good control of annual weeds, but not of perennials. It is difficult to quantify the amount of clover material needed for sufficient weed control in different vegetables. However, 6, 9 and 12 tonnes DM ha^{-1} for white cabbage, red beet and carrots, respectively. From a holistic point of view; the use of clover material has also given promising control of pests, especially in carrots, as well as having substantial nutritional value when used as either green manure or mulch.

Naseem *et al*. (2009) tested Allelopathic influence of sunflower plant water extract (1:10 w/v) against weeds and wheat under field conditions. Treatments applied were sunflower plant water extract at pre-emergence, at 25 DAS (days after sowing), pre-emergence + 25 DAS, 25+35 DAS, preemergence + 25 + 35 DAS and control. Wheat variety Inqlab-91 was sown on 13th November, 2005. The inhibitory effects of pre-emergence application on germination of *Phalaris minor* were higher, whereas wheat remained unaffected at this stage of application. Application of water extract at pre-emergence + 25 DAS, 25 + 35 DAS and pre-emergence + 25 + 35 DAS suppressed the growth of *Phalaris minor* Retz., *Chenopodium album* L., *Coronopus didymus* L. and *Avena fatua* L. Inhibitory effects were species specific and increased with increasing the water extract application frequency. All the treatments except preemergence + 25 + 35 DAS increased the wheat yield significantly over control.

Parthenium (*Parthenium hysterophorus* L.), an annual invasive weed native to tropical America, is rapidly spreading in many parts of the world. Javaid *et al*. (2008) designed to manage this weed by exploiting allelopathic potential of rice (*Oryza sativa* L.). In a laboratory bioassay, effect of aqueous, methanol and -hexane shoot extracts of 0, 2, 4 and 10% concentrations of three rice varieties viz. Basmati-385, Basmati-386 and Basmati Super was tested against germination and seedling growth of parthenium. Aqueous and methanol extracts exhibited phytotoxicity against the test weed species.

Ashrafi *et al.* (2007) reported that Barley [*Hordeum vulgare* (L.) Koch.] contained water soluble allelochemicals that inhibit the germination and growth of other species. Growth of Wild Barley, as indicated by plant height and weight, was significantly reduced when grown in soil previously cropped to Barley compared with that cropped to Wild Barley. In bioassays, Barley extracts reduced Wild Barley hypocotyl length, hypocotyl weight, radicle weight, seed germination, and radicle length by as much as 44, 57, 61, 68 and 79 %, respectively, when compared with water control. Increasing the water extract concentrations from 4 to 20 g per 100 ml of water of all Barley parts significantly increased the inhibition of Wild Barley germination, seedling length and weight. Based on 8-day-old wild barley radicle length, averaged across all extract concentrations, the degree of toxicity of different Barley plant parts can be ranked in the following order of inhibition: leaves > flowers > mixture of all plant parts > stems > roots.

Severino and Christoffoleti (2004) designed a field experiment to determine the effect of the green manure species *Crotalaria juncea*, *Arachis pintoi* and pigeon pea on the weeds *Brachiaria decumbens*, guineagrass and hairy beggarticks, and on the natural weed infestation in the inter rows area of an avocado orchard. The weed species were suppressed differently by each green manure species. When the green manure was incorporated into the top 5 cm of soil or left on the surface, in a greenhouse experiment, the emergence of weed seeds was significantly inhibited, depending on the species, and on the amount and depth of green manure incorporation.

Tawaha and Turk (2003) observed that soil incorporation of fresh black mustard roots and both roots and shoots reduced wild barley germination, plant height and weight when compared with a no-residue control. In bioassays, black mustard extracts reduced wild barley hypocotyl length, hypocotyl weight, radicle weight, seed germination, and radicle length by as much as 44, 55, 57, 63 and 75 %, respectively, when compared with a water control. Increasing the water extract concentrations from 4 to 20 g per 100 ml of water of all black mustard parts significantly increased the inhibition of wild barley germination, seedling length and weight.

Turk and Tawaha (2003) reported that black mustard (*Brassica nigra* L.) contained water-soluble substances that inhibited the germination and seedling growth of wild oat (*Avena fatua* L.). Aqueous extracts of *B. nigra* leaf, stem, flower and root plant part were made to determine their effects on germination and dry weights of hypocotyl and radicle length of 8-d old *A. fatua* L. seedlings over a range of extract concentrations. Increasing the aqueous extract concentrations of separated *B. nigra* L., plant parts significantly inhibited *A. fatua* L. germination, seedling length and weight. Radicle length was more sensitive to extract source than seed germination or hypocotyl length. Soil incorporation of fresh *B. nigra* roots only or both roots and shoots reduced *A. fatua* emergence, plant height, and dry weight per plant.

2.4 Effect of variety

2.4.1 Effect on growth characters

Saffari and Torabi-Sirchi (2011) conducted an experiment to estimate the effects of different concentrations of two native Iranian wheat (Alvand and Falat) straw extracts on germination, radicle growth, coleoptile length, plant height, leaf area (LA), wet weight (WW) and dry weight (DW) of two hybrid corn varieties (single cross 704 and single cross 647). They reported that the straw extracts, have negative and significant effects on both corn varieties' growth and the significant allelopathic effects remained up to 90 days after wheat harvest; but decreased gradually up to 180 days after harvest. They also advised that before corn cultivation, wheat straw and residues should be eliminated from the field to avoid negative allelopathic effects of wheat straw on corn growth. Hence, it is recommended to let no-till fields as fallow for 6 months; to acquire convenient growth and high yield for corn.

Jefferson and Pennacchio (2003) tested the allelopathic potentiality of the aqueous and methanol extracts of the leaves of four Chenopodiacea species viz., *Atriplex bunburyana* F. Muell., *Atriplex codonocarpa* Paul G. Wilson., *Maireana georgei* (Diels) Paul G. Wilson and *Enchylaena tomentosa* R. Br. at 0.006, 0.06, 0.63, 1.55, 3.12, 6.25 g l-1 and 0.025, 0.25, 2.5, 6.25, 12.5, 25 g l-1 respectively, for allelopathy on lettuce seeds as well as on the chenopod species themselves. They found that germination of lettuce seed was inhibited at concentrations ranging from 3.12 and 6.26 g l-1. The root and shoot growth of lettuce was also inhibited. These authors also observed the inhibitory effect of the extracts of the leaves of *Atriplex bunburyana* and *Atriplex codonocarpa* on the seed of the chenopods, *Enchylaena tomentosa* and *Maireana georgei*. However, *A. codonocarpa* was not, in contrast, affected by extracts derived from the leaves of *E. tomentosa* and *M. georgei*. At the same time all four species were susceptible to allelopathy by extracts isolated from leaves of their own respective species. These results indicated that allelopathy could be considered as a possible mechanism controlling the timing of chenopod germination and seedling establishment.

Xuan and Tsuzuki (2002) studied eight common varieties of Japanese alfalfa (*Medicago sativa* L.), namely Batasu, Hisawakaba, Kitawakaba, Makiwakaba, Natsuwakaba, Lucerne, Tachiwakaba and Yuba. Aqueous extracts of both fresh and dried material of alfalfa plants of all varieties significantly inhibited both germination and growth of lettuce (*Lactuca sativa* L.). Leachates from germinating seeds of almost all alfalfa varieties inhibited elongation of the radicle but produced a negligible increase in germination and only slightly inhibited elongation of the hypocotyl of lettuce plants. Results demonstrated that the degree of inhibition of germination and growth of lettuce varied with the variety of alfalfa. In particular, Lucerne was identified as having the strongest allelopathic potential of the varieties studied. The results suggested that the allelopathic potential of alfalfa might be relating to a gene.

2.4.2 Effect on weed

Biswas *et al.* (2011) conducted a field experiment in SRI (system of rice intensification) at Agronomy field of Sher-e-Bangla Agricultural University, Bangladesh during December 2010 to May 2011 including 16 popular inbred and hybrid rice varieties. They concluded that at 30 DAT, the significantly highest weed population of 119.00 and 117.00 m^{-2} was found in BRRI dhan29 and BRRI dhan45 respectively whereas BR3 and BRRI dhan50 resulted the lowest weed population of 31.00 and 38.00 m^{-2} respectively. Similar lowest weed population i.e. 35.33 and 36.00 m^{-2} was also found in BRRI dhan50 and BRRI hybrid dhan1 respectively at 60 DAT.

Noguchi and Salam (2008) observed that rice allelopathy has received much attention, and might be an alternative to the chemical and mechanical control of weeds to reduce use of chemical herbicides. It was therefore of interest to assess the allelopathic potential of Bangladesh rice cultivars for weed control purposes. The allelopathic potential of 102 Bangladesh rice (42 high yielding and 60 traditional cultivars) was determined against the seedling growth of cress, lettuce, *Echinochloa crusgalli* and *E. colonum.* High yielding rice cultivars, BRRI dhan37, BRRI dhan30 and BRRI dhan38, respectively, had the most significant inhibiting effect on the growth of cress, lettuce and *E. colonum,* and traditional rice cultivar, Kartikshail had the most significant inhibiting effect on barnyard grass. The high yielding rice cultivar, BR 17 marked the greatest inhibitory activity with an average of 39.5% of the growth inhibition on roots and hypocotyls/shoots of cress, lettuce, barnyard grass and *E. colonum.*

Parthenium (*Parthenium hysterophorus* L.), an annual invasive weed native to tropical America, is rapidly spreading in many parts of the world. Javaid *et al*. (2008) designed to manage this weed by exploiting allelopathic potential of rice (*Oryza sativa* L.). In a laboratory bioassay, effect of aqueous, methanol and -hexane shoot extracts of 0, 2, 4 and 10% concentrations of three rice varieties viz. Basmati-385, Basmati-386 and Basmati Super was tested against germination and seedling growth of parthenium. Aqueous and methanol extracts exhibited phytotoxicity against the test weed species.

Biswas *et al*. (2008) reported that wheat crop was frequently affected by weeds that cause about 20 to 30% yield reduction. A two year research project was initiated at Agronomy department, Sher-e-Bangla Agricultural University, Bangladesh to study the allelopathic effects of *Brassica* spp. to control weeds in wheat. *Brassica* crops were uprooted at initiation of flowering and applied in the same field. *Amaranthus spinosus, Amaranthus viridis, Heliotropium indicum, Polygonum hydropiper, Celosis argentina, Ageratum conyzoides, Brassica kaber and Digitaria ischaemum* were not found to the wheat field. The highest weed dry matter yields was recorded in *Brassica juncea* plots (1.72 g/m^2) at 30 DAS and in *Brassica napus* field (1.44 g/m^2) at 50 DAS. The lowest weed dry matter (0.89 g/m^2) was recorded when total *Brassica* biomass was incorporated into the soil in 30 DAS and 50% incorporation plus 50% spreading in 50 DAS. Weed population densities were not affected by *Brassica* species in 30 and 50 DAS and by the incorporation methods 50 DAS, although the lowest weed population (15.33/m^2) was recorded in spreading between lines that were similar to complete incorporation and 50% spreading plus 50% incorporation in 30 DAS. Interaction of *Brassica* species and incorporation methods showed lowest weed dry matter (0.74 g/m^2) in 30 DAS with *Brassica napus* biomass incorporated into the soil.

Dhima *et al.* (2006) conducted a study to measure the effect of two barley (*Hordeum vulgare* L.) and six triticale (X *Triticosecale* Withmack) cultivars and three rye (*Secale cereale* L.) populations, used as cover crops, on the emergence and growth of barnyard grass [*Echinochloa crus-galli* (L.) P. Beauv.], bristly foxtail [*Setaria verticillata* (L.) P. Beauv.], large crabgrass [*Digitaria sanguinalis* (L.) Scop.], and sugarbeet (*Beta vulgaris* subsp. *vulgaris*). In the field, barnyard grass, bristly foxtail and large crabgrass emergence in mulched plots was 39 to 69%, 0 to 34%, and 0 to 78% lower, respectively, as compared with that in mulch-free plots. They also suggest that Athinaida barley and the rye from Albania could be used as cover crops for annual grass weed suppression in sugarbeet.

Bala *et al.* (2005) examined the effects of wood chip eluates from the five species of black walnut (*Juglans nigra* L.). Among them a species was identified to have weed-suppressing allelochemicals. Tests on red cedar, red maple and neem showed that water-soluble allelochemicals were present not only in the wood but also in the leaves. In greenhouse trials, red cedar wood chip mulch significantly inhibited the growth offlorida beggarweed (*Desmodium tortuosum* DC.), compared to the gravel-mulched and no-mulch controls

Chung *et al*. (2003) described the effect of allelopathic potential of rice (*Oryza sativa L*.) residues against *Echinochloa crusgalli* P. Beauv. var. oryzi-cola Ohwi (barnyardgrass), an associated weed of paddy. It was found that average inhibition by the variety Duchungjong on *Echinochloa crusgalli* was 77.7% higher than other 113 tested varieties. Early and late maturing varieties showed less inhibitory effect of 50.2% and 56.1% respectively and intermediate rice varieties with 59.3% inhibition, although the difference between the intermediate and late-maturing groups was not significant.

Fujii (2001) stated that leguminous cover crops such as hairy vetch (*Vicia villosa*) and velvetbean (*Mucuna pruriens*), graminaceous cover crops, such as oat (*Avena sativa*) and rye (*Secale cereale*), certain cultivars of wheat (*Triticum aestivum*) and barley (*Hordeum vulgare*) were promising. Fall-sown cover crops such as hairy vetch, rye, wheat, oat, grass pea, and mustard were more effective when compared to spring-sown cover crops. Hairy vetch was most promising for the weed control in abandoned fields because of its ability to die off during summer season to make thick straw-like mulch.

In Philippines, 111 rice cultivars have been evaluated for weed suppression capability against barnyardgrass under field conditions over three seasons (Olofsdotter *et al.,* 1999). They correlated screening results from the laboratory with a range of competition components, measured in the field, and claimed that allelopathy can give 34% of the reduction in total weed dry weight after 8 wks of seeding. There appears to be a higher frequency of allelopathic varieties among tropical Japonicas within *Oryza sativa* and among *O. glaberrima* accessions than in other varietal groups (Courtois and Olofsdotter, 1998).

Olofsdotter and Navarez (1996) in both laboratory screening and field experiments revealed that rice allelopathy was active against both monocot and dicot weeds. A rice cultivar (Taichung Native 1) has also shown activity against most of the weeds including barnyardgrass, desert horsepurslane (*Trianthema portulacastrum* L.), ducksalad, and toothcup (*Ammannia coccinea* Rottb.).

Friedman *et al.* (1995) examined five cover crop species on nitrogen production and weed suppression in Sacramento Valley Farming Systems and found that the Lana vetch mixes and the Lana vetch provided more effective weed control than the purple vetch in both years. In 1993-94, weeds were negligible in all Lana vetch treatments, while the weeds in the purple vetch treatment made up almost 35% of the total biomass. In 1994-95, the Lana vetch and fava/Lana vetch treatments were considerably more effective at choking out weeds than the purple vetch, although the cowpea/Lana vetch treatment was not more effective. However, the vetch in mix was unable to compete effectively with the heavy weed growth.

CHAPTER 3

MATERIALS AND METHODS

This chapter is presenting a brief description of the experimental site, soil, climate, experimental design, treatments, cultural operations, collection and preparation of soil samples and analyses of different parameters for both *Brassica* sp. and lentil under the following headings-

3.1 Location

The experiment was carried out during rabi season (October to March) of 2011–12, at the central farm of Sher-e-Bangla Agricultural University, Dhaka-1207. The experimental field was located at $90^{0}22'$ E longitude and $23^{0}41'$ N latitude at an altitude of 8.6 meters above the sea level. The experimental site was located under the agro-ecological region of “Madhupur Tract” (AEZ No. 28).

3.2 Climate

The experimental area falls under the sub-tropical climate that is characterized by high temperature, high humidity and heavy rainfall with occasional gusty winds in kharif season (April-September) and less rainfall associated with moderately low temperature during the *rabi* season (October-March).

3.3 Soil

The farm belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. The land was above flood level and sufficient sunshine was available during the experimental period.

3.4 Crop/planting material

3.4.1 Description of *Brassica* cultivar Tori 7

The *Brassica* cultivar Tori 7 was developed by Oilseed Research Centre, BARI in 1976. It belongs to *B. campestries*. Seed color is brown. Plant is dwarf type and plant height is 70-80 cm. The variety takes 70-80 days to mature. Susceptible to Leaf blight disease. Major insect is Brassica Aphid. Harvesting time January and potential seed yield is 950-1100 Kg ha^{-1}.

3.4.2 Description of *Brassica* cultivar BARI Sarisha 8

BARI Sarisha 8 was developed by Oilseed Research Centre, BARI in 1994. It belongs to *B. napus.* Leaves are hairless and look like leaves of cauliflower. Waxy coating on leaf is found. Siliquae are two chambered. Optimum sowing time is Mid-October to Mid-November. It is a short duration variety which matures at 95-100 days. Susceptible to Leaf blight disease. Major insect is Brassica Aphid. Harvesting time is January-February seed yield is 2.1-2.4 t ha^{-1}.

3.4.3 Description of *Brassica* cultivar BARI Sarisha 11

BARI sarisha 11 was developed by Oilseed Research centre, BARI in the year of 2000. It belongs to *B. juncea* and is a tall plant variety. Siliquae are appressed in the inflorescence. Seed are brown in colour and bold Resistant to *Orobanche.* The variety is drought & salinity tolerant so it is suitable for Khustia, Jessore and Khulna. It is Suitable for late cultivation. It is a short duration variety which mature at 110-120 days and seed yield is 2.0 - 2.4 t ha^{-1}. Optimum sowing time is Mid October-mid November and harvesting time January-February.

3.4.4 Description of *Brassica* cultivar BARI Sarisha 13

BARI sarisha 13 was developed by Oilseed Research Centre, BARI in the year of 2004. It belongs to *B. napus.* Prolong flowering time, slightly tolerate water logged condition, slightly tolerant to *Alternaria* leaf blight are the main feature of this variety. Crop duration is short which mature at 90-95 days. Yield (ton/ha) seed yield is 2.2-2.8 t ha^{-1}. Optimum sowing time is Mid October-mid November and harvesting time January-February. Major disease of this variety is leaf blight and major insect is Aphid.

3.4.5 Description of *Brassica* cultivar BARI Sarisha 15

Dark brown coloured and bold seeded BARI Sarisha 15 is a drought tolerant variety. It is under *Brassica campestris* group. It is a tall plant and siliquae are appressed in the inflorescence. The variety is resistant to *Orobanche*. It takes 75-80 days to mature and yield potentiality is 2.15–2.5 t ha^{-1}.

3.4.6 Description of lentil cultivar BARI Masur 6

BARI Masur 6 is a modern lentil variety released by Pulses Research Centre, Ishurdi, Pabna, BARI in 2006. The plant height is about 40 cm. It is a small bushy plant. The variety is semi-dwarf, early maturing and high yielding. Leaves are deep green. It takes 110-115 days to maturity. The suitable growing place of BARI Masur 6 is most of the Pulse growing area of Bangladesh. The optimum sowing time of BARI Masur 6 is Mid October to Mid November and optimum harvesting time is Mid February to Mid March. It can be grown under both optimum and late seeding conditions. The spacing should be maintained (40x10 cm) .The major diseases of BARI Masur 6 are Stemphylium blight and Foot rot. This can be overcome by using resistant variety. Seed treatment with provex-200wp @ 0.25% kg seed used to control foot rot and other seed borne diseases. Chemical approach: Rovral 50WP and Secure 600 @ 0.2% 3 times 7 days interval used to control Stemphylium blight of lentil. Yield of BARI Masur 6 is 2500 kg ha^{-1}.

3.5 Experimental treatments

There were eleven sets of treatments in the experiment. The treatments are shown below;

T_1 = Control (No biomass or no spray)

T_2 = Tori 7-Biomass incorporated @ 2.6 t ha^{-1} at sowing

T_3 = Tori 7-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil

T_4 = BARI Sarisha 8-Biomass incorporated @ 2.6 t ha^{-1} at sowing

T_5 = BARI Sarisha 8-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil

T_6 = BARI Sarisha 11-Biomass incorporated @ 2.6 t ha^{-1} at sowing

T_7 = BARI Sarisha 11-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil

T_8 = BARI Sarisha 13-Biomass incorporated @ 2.6 t ha^{-1} at sowing

T_9 = BARI Sarisha 13-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil

T_{10} = BARI Sarisha 15-Biomass incorporated @ 2.6 t ha^{-1} at sowing

T_{11} = BARI Sarisha 15-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil

3.6.1 Collection of *Brassica* biomass

Required amount of *Brassica* biomass of different varieties (Tori 7, BARI Sarisha 8, BARI Sarisha11, BARI Sarisha 13 and BARI Sarisha 15) for the experiment was grown and collected from nearby field of the experimental area with 20 m^2 of each variety. Sowing was done on 30th October, 2012 and uprooted on 29th November, 2012.

3.6.2 Layout of experiment

The experiment was laid out in completely randomized block design with three replications. The experimental unit was divided into three blocks each of which representing a replication. Each block was divided into eleven plots where one plot kept control (no *Brassica* incorporated or no spraying of *Brassica* biomass extract). Five plots with 30 days old *Brassica* biomass and the rest five plots sprayed with water extract of 30 days old *Brassica* biomass of five different varieties at 30 and 60 DAS of lentil. So, the total number of plots in the entire experiment was 33. BARI Masur6 was sown in all the plots on 30th October, 2012. Size of each unit plot was 3 m × 2.5 m = 7.5 m^2. The distance maintained between plot-plot was 1m and between blocks was 0.5m (Figure 1).

3.7 Details of the field operations

The particulars of the cultural operations carried out during the experimentation presented below:

3.7.1 Land preparation

The experimental field was first opened on 25th October, 2011 with the help of a power tiller and prepared by three successive ploughings and cross-ploughings. Each ploughing was followed by laddering to have a desirable fine tilth. The visible larger clods were hammered to break into small pieces. All kinds of weeds and residues of previous crop were removed from the field. The *Brassica* variety Tori7, BARI sarisha8, BARI sarisha11, BARI sarisha13 and BARI sarisha15 were sown in the nearby field on 30th October, 2011. Of all 5 *Brassica* varieties was done at their 30 DAS (29.11.11). The half of the biomass was incorporated with soil as per experimental treatment and the rest half were kept to make dry matter by sun drying. Same procedure was followed for the 5 *Brassica* varieties consecutively in 3 blocks. The final land preparation was done on the same day 29th November 2011 and layout was done as per experimental design. Individual plots were cleaned and finally leveled with the help of wooden plank. The collected *Brassica* biomass was incorporated to the soil during final land preparation following experimental design.

3.7.2 Fertilizer application

The *Brassica* field was fertilized with urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum, zinc sulphate and boric acid at the rate of 250-170-85-150-5 and 10 kg ha^{-1} respectively. Half of the fertilizer dose was applied at final land preparation, because *Brassica* was uprooted after almost half (one month) life. The main experimental field was fertilized with urea, TSP, MoP, and gypsum $hectare^{-1}$ @ 62 kg, 101 kg, 46 kg, and 19 kg, respectively. The whole amount of triple super phosphate (TSP), muriate of potash (MoP), gypsum and urea were mixed with soil at the time of final land preparation.

3.7.3 Collection and sowing of seeds

The *Brassica* seeds (Tori 7, BARI Sarisha 8, BARI Sarisha 11, BARI Sarisha 13 and BARI Sarisha 15) were collected from Oilseed Research Centre, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. At good tilth condition seeds were sown on 30th October, 2011. Furrows were made with hand rakes for sowing. Seeds were sown continuously in line. The line to line distance was maintained at 30 cm. After sowing seeds were covered with soil and slightly pressed by hand. The lentil seeds (cv. BARI Masur 6) were collected from Pulses Research Centre, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Furrows were made for sowing when the land was in proper joe condition. On 29th November, 2011 seeds were sown continuously with maintaining 30 cm line to line distance. After sowing, seeds were covered with soil and slightly pressed by hand.

3.7.4 Drying of *Brassica* biomass

After incorporation of green *Brassica* biomass @ 0.5kgm^{-2} to the respective plots of the field as per treatment. The rest half *Brassica* biomass of five different varieties were dried by sun drying and stored separately. This dry biomass was used to spraying in the lentil field in two equal installments through water extract.

3.7.5 Spraying of *Brassica* biomass in the lentil field

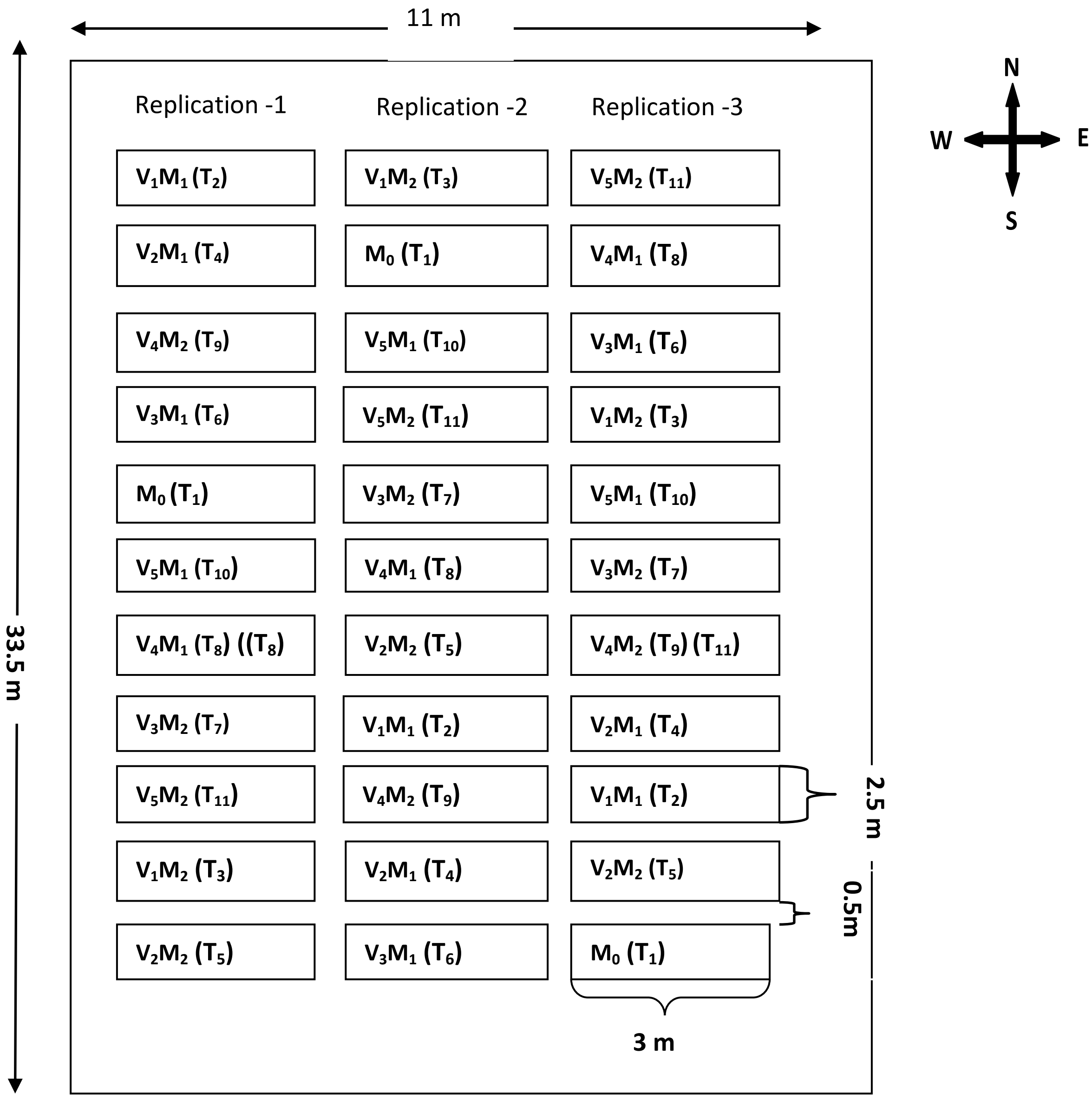
The species wise stored dry biomass was divided into two parts. One part was soaked in water over night and the extract was sprayed in the plots at 30 DAS of lentil. The rest half was also prepared in the same way and sprayed at 60 DAS of lentil.

3.7.6 Irrigation

The experimental plot was irrigated three times. The first, second and third irrigations were done at 15, 30 and 50 days after sowing respectively. Proper drainage system was maintained to remove the excess amount of water from the plot.

3.7.7 Pest management

In the whole period of experimentation, there were no severe infestation of diseases and pests were observed. Dithane M-45 was sprayed once to control pest of lentil. Special attentions were undertaken to protect the crop from the attack of parrots, pigeons and other birds.



V_1 = Tori7

V_2= BARI Sarisha8

V_3= BARI Sarisha11

V_4= BARI Sarisha13

V_5= BARI Sarisha15

M_0=No *Brassica* materials

M_1 = *Brassica* biomass incorporated to the soil

M_2= *Brassica* dry biomass water extracts sprayed to the soil

Figure 1. Layout of the experimental plot containing combination of treatments in individual plot

3.7.8 Harvesting and sampling

The lentil crop was harvested at maturity on March 10, 2012. Samples were collected from different places of each plot leaving undisturbed middle five rows in the center. The selected sample plants were then tagged and carefully carried out to the threshing floor in order to collect data. Plants of central 3.75 m^2 and the rest crop was harvested separately plot-wise, bundled and tagged. The crop bundles were sun dried and the grains and straw were separated by beating with the wooden stick and dried for constant moisture and the weight were recorded and converted into t ha^{-1} basis.

3.8 Recording of data

The following data were collected during the study period:

3.8.1 Data regarding weed

1. Number of weed population at 30 and 60 DAS of lentil
2. Dry matter weight of weeds at 30 and 60 DAS of lentil

3.8.2 Data regarding different crop characters and yield of lentil

a. growth:

1. Plant height (cm) at 30 days interval
2. Dry matter weight of plant at 30 days interval
3. Days to maturity

b. Yield contributing characters

1. Number of branches $plant^{-1}$
2. Number of pods $plant^{-1}$
3. Number of grains pod^{-1}

4. Weight of 1000 grains (g)

c. Yield

1. Grain yield (t ha^{-1})

2. Straw yield (t ha^{-1})

3. Biological yield (t ha^{-1})

4. Harvest index (%)

5. Shelling percentage

3.8.1.1 Weed population

From the 1 m^2 area of each plot, the total weeds were uprooted and the species were counted at 30 and 60 DAS of lentil respectively.

3.8.1.2 Dry weight of weed biomass

The fresh weeds were counted and oven dried at 80^0C until a constant weight was obtained. The sample was then transferred into desiccators and allowed to cool down to the room temperature and then final weight of the sample was taken at 30 and 60 DAS of lentil respectively.

3.8.2 Yield contributing characters and yield of lentil

3.8.2.1 Plant height

The height of ten plants were recorded in centimeter (cm) at 30, 60, 80 DAS and at harvest from the same pre-selected plants. To measure plant height ten plants were randomly selected from each plot and tagged. The height was measured from base of soil surface to tip and mean height was recorded.

3.8.2.2 Dry weight of plant biomass

Ten plants were uprooted randomly from the selected lines of each plots at inner rows of the plot at 30, 60, 80 DAS and at harvest and then oven dried at 80ºC until a constant weight was obtained. The sample was then transferred into desiccators and allowed to cool down to the room temperature and then final weight of the sample was taken. The final weight was averaged and thus dry weight of each plant was found.

3.8.2.3 Number of branches plant^{-1} at harvest

At harvest, ten (10) plants were selected randomly and counted their total branches. Then the total number of branches was averaged and thus the number of branches of individual plant was calculated.

3.8.2.4 Number of pods plant^{-1}

At harvest, ten (10) plants were selected randomly and counted their total pods. Then the total number of pods was averaged and thus the number of pods of individual plant was measured.

3.8.2.5 Number of grains pod^{-1}

When the lentil plants become mature, ten (10) pods were selected randomly and counted their total grains. Then the total number of grains was averaged and thus the number of grains of individual pod was measured.

3.8.2.7 1000 grain weight (g)

Thousand grains were counted from the seed sample and weighed at about 12% moisture level using an electric balance and recorded.

3.8.2.8 Grain yield

Inner five rows ($3.75m^2$) areas of each plot were harvested for recording yield data. After threshing, proper drying (12% moisture level) and cleaning, yield of each sample plot was weighed and values were converted to t ha^{-1}.

3.8.2.9 Straw yield

Inner five rows ($3.75m^2$) areas of each plot were harvested from which straw weight was determined after threshing and drying and finally converted them into t ha^{-1}.

3.8.2.10 Biological yield

Biological yield was determined by adding grain yield and straw yield of the total area.

Biological yield = Grain yield + straw yield

3.8.2.11 Harvest index

Harvest index (%) was determined by dividing the economic (grain) yield by the total biological yield (grain yield + straw yield) from the same area (Gardner *et al.* 1985) and multiplying by 100.

$$\text{Harvest index (\%)} = \frac{\text{Grain yield (t ha}^{-1}\text{)}}{\text{Biological yield (t ha}^{-1}\text{)}} \times 100$$

3.8.2.12 Shelling percentage

The mass of seeds obtained from the pods that were randomly drawn from the bulk sample was used to calculate the shelling percentage.

$$\text{Shelling percentage} = \frac{\text{Seed mass}}{\text{Pod mass}} \times 100$$

3.9 Statistical analysis

The experiment was conducted following completely randomized block design. The collected data were analyzed by MSTAT–C software. The means for all recorded data were calculated and the analyses of variance of all characters were performed. The mean differences were evaluated by Duncan's Multiple Range Test (DMRT) at 0.05 level of probability (Gomez and Gomez, 1984).

CHAPTER 4

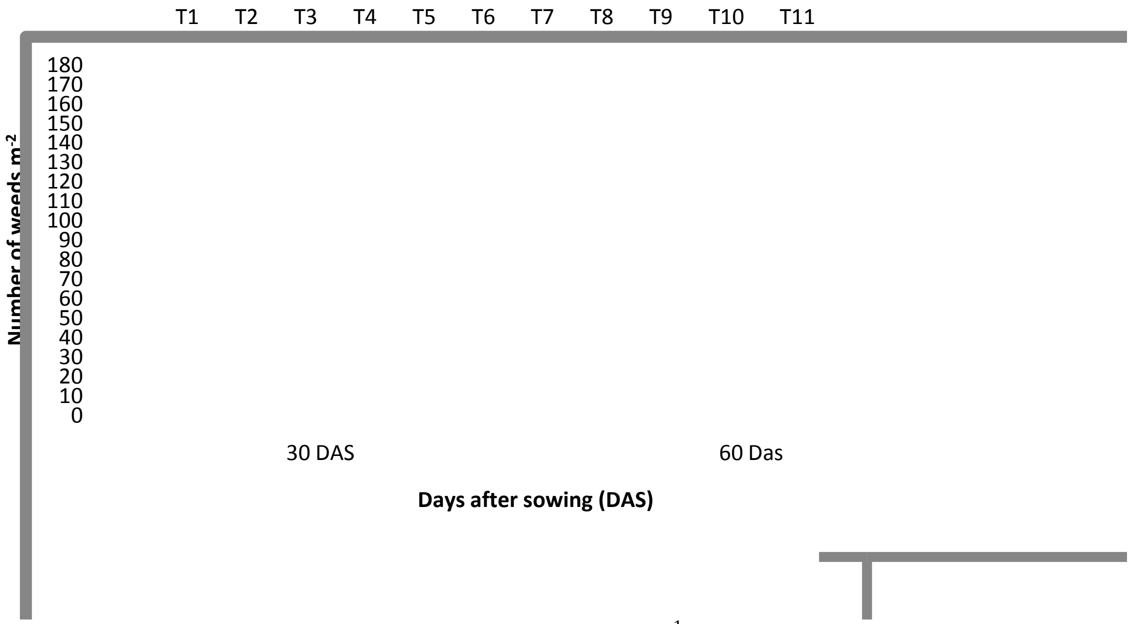
RESULTS AND DISCUSSION

The experiment was conducted to study the allelopathic effect of *Brassica* biomass and water extract of *Brassica* biomass on weed control and yield of lentil. The analysis of variance data on different crop and yield contributing characters as well as yield of lentil as influenced by *Brassica* biomass and water extract of *Brassica* biomass has been presented and interpreted in this chapter.

4.1 Number of weeds m^{-2}

Significant variations were found for number of weeds m^{-2} at 30 DAS and 60 DAS (Appendix I). At 30 DAS, the maximum number of weeds (164.00) m^{-2} was measured from the treatment T_1 (no biomass) that was significantly different from other treatments. The minimum number of weeds m^{-2} (62.00) was found from the biomass application of Tori7 which was incorporated with soil during sowing time of lentil (T_2) that statistically at par with T_9. At 60 DAS, the highest number of weeds m^{-2} (169.00) was obtained from the treatment T_1 (no biomass) and statistically similar with T_3. The lowest number of weeds was (70.00) m^{-2} measured from the biomass application of BARI sarisha11 which was sprayed at 30 and 60 DAS of lentil (T_7) that statistically at par with T_2 (Figure 2).

Similar results found by Rahman *et al.* (2012b) who noted that weed population and weed dry weight showed the highest result in fallow land with no biomass application. This results also in agreement with Tawaha and Turk (2003) who stated that growth of wild barley, as indicated by plant height and weight, was significantly reduced when grown in soil previously cropped to black Brassica compared with that cropped to wild barley. These results disagree with Biswas *et al.* (2011) who stated that weed population in rice field varied for varietal variation. Similar result was found by Uremis *et al*. (2009) who reported that the allelopathic potential of residues of some *Brassica* species suppressed Johnson grass under both laboratory and field conditions. The result was also in agreement with the findings of Boydston (2008) who reported that Brassicaceae cover crops suppressed weeds due to fast emergence and vigorous competitive growth during fall establishment and allelopathic substances released during degradation of the cover crop residues. Arlauskiene, A. and Maiksteniene, S. (2006) also showed that under sown intercrops (*Trifolium pratense* L., *Lolium multiflorum* Lam., *Dactylis glomerata* L.), reduced the number of weeds in cereals on average 13.90%.



T_1=Control, T_2=Tori 7-Biomass incorporated @ 2.6 t ha^{-1} at sowing**,** T_3=Tori 7–Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil**,** T_4=BARI Sarisha 8–Biomass incorporated @ 2.6 t ha^{-1} at sowing**,** T_5=BARI Sarisha 8-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil**,** T_6=BARI Sarisha 11-Biomass incorporated @ 2.6 t ha^{-1} at sowing**,** T_7=BARI Sarisha 11-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil**,** T_8=BARI Sarisha 13–Biomass incorporated@ 2.6 t ha^{-1} at sowing, T_9=BARI Sarisha 13-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil**,** T_{10}=BARI Sarisha 15 –Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_{11}=BARI Sarisha15-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil

Figure 2. Effect of *Brassica* biomass and water extract on number of weeds in lentil field (SE=2.48 and 2.39 for 30 and 60 DAS)

4.2 Dry weight of weeds m^{-2}

Significant variations were found for dry weight of weeds m^{-2} at 30 DAS and 60 DAS (Appendix I). At 30 DAS, the highest dry weight of weeds m^{-2} (4.80g) was found from treatment T_1 (no biomass) which was not statistically identical with others. The lowest dry weight of weeds m^{-2} was (1.17 g) measured from the biomass application of BARIsarisha13 which was sprayed at 30 and 60 DAS of lentil (T_9) and not statistically at par with others.

At 60 DAS, the maximum dry weight of weeds m^{-2} (16.10 g) was measured from the treatment T_1 (no biomass) that statistically similar with T_8. The minimum dry weight of weeds m^{-2} (6.63 g) was found from the biomass of Tori7 which was incorporated with soil during sowing time of lentil (T_2) that statistically at par with T_5 (Table 1).

Similar results obtained by Rahman *et al.* (2012b) who noted that weed population and weed dry weight showed the highest result in fallow land with no biomass application. This results also in agreement with Uremis *et al*. (2009) who evaluated the allelopathic potential of residues of some *Brassica* species where all species suppressed Johnson grass in field and laboratory conditions. These results also agree with the findings of Cheema *et al*. (2008) who investigated that inclusion of allelopathic crops in rotation systems for weed suppression by early post-emergence application of the mixture of sorghum, sunflower, *Brassica* or mulberry water extracts suppressed total weed dry weight by 40 to 75%.

4.3 Plant height

Significant variations were found for height of the lentil at 30, 60and 80 DAS and at harvest (Appendix II). At 30 DAS, the highest plant height (10.07 cm) was measured from the biomass application of BARI sarisha11 which was incorporated with soil during sowing time of lentil (T_6) that statistically similar with T_4, T_7, T_1, T_9 and T_{10}. The lowest plant height (7.91 cm) was found from the water extract of Tori7 which was sprayed at 30 and 60 DAS of lentil (T_3) that statistically at par with T_8, T_5, T_2, T_{10} and T_{11}. At 60 DAS, the highest plant height (20.20 cm) was obtained from T_1 (control) which was statistically similar with T_2, T_3, T_4, T_6, T_8, T_9, T_{10} and T_{11}. The lowest lentil height was (18.27 cm) measured from the water extract of BARI sarisha8 which was sprayed at 30 and 60 DAS of lentil (T_5) that statistically at par with T_2, T_3, T_4, T_7,T_8 and T_{11}. At 80 DAS, the highest plant height (30.21 cm) was measured from the biomass application of

Table 1: Dry weight of weeds in lentil field having dry biomass and water extract of *Brassica*

Treatments	Dry weight of weeds m^{-2} (g)	
	30 DAS	60 DAS
T_1	4.80	16.10
T_2	1.70	6.63
T_3	2.30	12.83
T_4	2.10	8.83
T_5	2.97	7.10
T_6	3.10	12.07
T_7	3.37	7.67
T_8	4.60	15.57
T_9	1.17	9.53
T_{10}	3.27	9.93
T_{11}	3.70	8.97
CV (%)	3.40%	4.62%
SE	0.06	0.28

T_1=Control, T_2=Tori 7-Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_3=Tori 7–Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_4=BARI Sarisha 8–Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_5=BARI Sarisha 8-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_6=BARI Sarisha 11-Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_7=BARI Sarisha 11-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_8=BARI Sarisha 13–Biomass incorporated@ 2.6 t ha^{-1} at sowing, T_9=BARI Sarisha 13-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_{10}=BARI Sarisha 15 –Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_{11}=BARI Sarisha15-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil

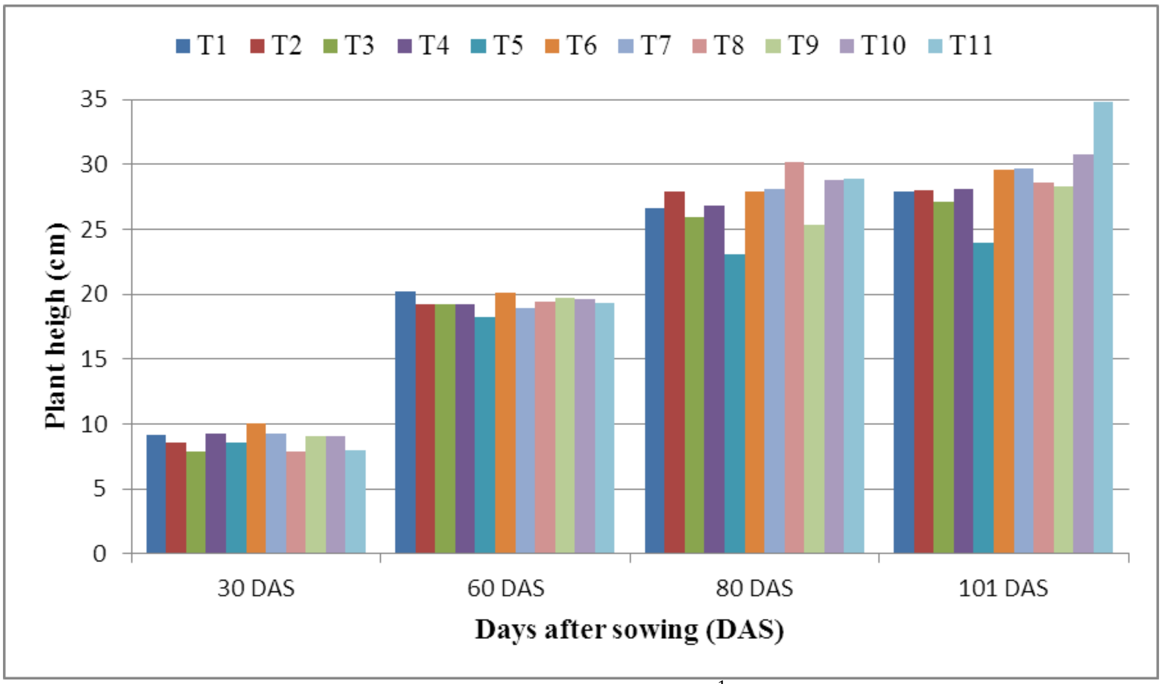
BARI sarisha13 which was incorporated with soil during sowing time of lentil (T_8) that statistically similar with T_1, T_2, T_3, T_4, T_6, T_7, T_9 and T_{10}. The lowest plant height (23.03 cm) was found from the water extract of BARI sarisha 8 that sprayed at 30 and 60 DAS of lentil (T_5) that statistically at par with T_1, T_2, T_3, T_4,

T_6 and T_9. At harvest, the highest plant height (34.81cm) was found from the water extract of BARI sarisha15 which was sprayed at 30 and 60 DAS of lentil (T_{11}) that was not statistically similar with others. The lowest plant height (23.99 cm) was measured from the water extract of BARI sarisha8 which was sprayed at 30 and 60 DAS of lentil (T_5) that statistically at par with T_3 (Figure 3).

These results agreed with Rahman *et al.* (2012b) who noted that land with *Brassica* and application of 35 days old *Brassica* biomass @ 0.5 -1.0 kg m^{-2} increased growth of wheat. Similar results also obtained by Khan *et al.* (2005) who showed that the allelopathic potential of aqueous extracts of leaves *Prosopis juliflora* and *Eucalyptus camaldulensis* and bark of *Acacia nilotica* significantly affect the germination percentage, seedling length (mm) and biomass yield (mg) $plant^{-1}$ of *Ipomoea* sp., *Asphodelus tenuifolius*, *Brassica campestris* and *Triticum aestivum.* This result was similar with the findings of Cheema *et al*. (2008) who concluded that inclusion of allelopathic crops in rotation systems for weed suppression by early post-emergence application of the mixture of sorghum, sunflower, Brassica or mulberry water extracts suppressed total weed dry weight. Tawaha and Turk (2003) also stated that soil incorporation of fresh black mustard roots and both roots and shoots reduced wild barley germination, plant height and weight when compared with a no-residue control.

4.4 Dry weight $plant^{-1}$

Insignificant variations were found for dry weight $plant^{-1}$ of lentil at 30 DAS, but significant at 60 and 80 DAS and at harvest (Appendix III). At 30 DAS, the numerically highest dry weight $plant^{-1}$ of the lentil (0.08 g) was found from the water extract of Tori7 which was sprayed at 30 and 60 DAS of lentil (T_3) and the lowest (0.06g) was obtained from $T_{1,}$ that statistically insignificant. At 60 DAS, the maximum dry weight $plant^{-1}$ of the lentil (0.85g) was measured from the water extract Tori 7 which was sprayed at 30 and 60 DAS of lentil (T_3) that statistically different with others. The minimum dry weight $plant^{-1}$ of the lentil (0.48g) was measured from the application of BARI sarisha11 that incorporated with soil during sowing time of lentil (T_6) and statistically similar with T_1, T_2, T_5, T_8, T_9



T_1=Control, T_2=Tori 7-Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_3=Tori 7–Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_4=BARI Sarisha 8–Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_5=BARI Sarisha 8-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_6=BARI Sarisha 11-Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_7=BARI Sarisha 11-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_8=BARI Sarisha 13–Biomass incorporated@ 2.6 t ha^{-1} at sowing, T_9=BARI Sarisha 13-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_{10}=BARI Sarisha 15 –Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_{11}=BARI Sarisha15-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil

Figure 3. Effect of *Brassica*, biomass and water extract on plant height of lentil (SE=0.41, 0.42, 1.75 and 1.80 for 30, 60, 80 DAS and at harvest)

and T_{11}. At 80 DAS, the highest dry weight $plant^{-1}$ of the lentil (2.40g) was found from the water extract of BARI sarisha11 which was sprayed at 30 and 60 DAS of lentil (T_7) that statistically at par with T_1, T_2, T_3, T_4, T_6, T_7, T_8, T_9, T_{10} and T_{11}. The lowest dry weight $plant^{-1}$ of the lentil (1.70g) was measured from the water extract of BARI sarisha8 that sprayed at 30 and 60 DAS of lentil (T_5) that statistically similar with T_1, T_2, T_3, T_4, T_6, T_8, T_9, T_{10} and T_{11}. At harvest, the highest dry weight $plant^{-1}$ of the lentil (3.83g) was found from the water extract of BARI sarisha11 which was sprayed at 30 and 60 DAS of lentil (T_7) and different with other treatments. The lowest dry weight $plant^{-1}$ of the lentil (2.53g) was measured from treatment T_1 (control) which was statistically similar with T_2, T_4, T_5 and T_6 (Figure 4).

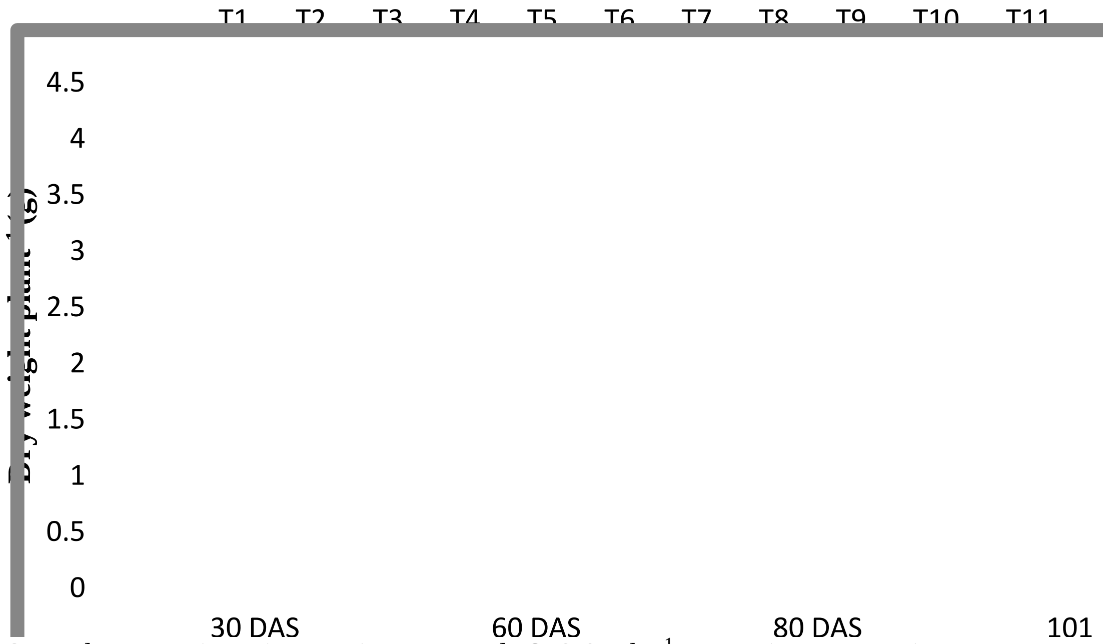
These results agreed with Rahman *et al.* (2012b) who noted that land with *Brassica* and application of 35 days old *Brassica* biomass @ 0.5 -1.0 kg m^{-2} increased growth of wheat. This results also in agreement with Khan *et al.* (2005) who showed that the allelopathic potential of aqueous extracts of leaves of *Prosopis juliflora* and *Eucalyptus camaldulensis* and bark of *Acacia nilotica* significantly affect the germination percentage, seedling length (mm) and biomass yield (mg) $plant^{-1}$ of *Ipomoea* sp., *Asphodelus tenuifolius*, *Brassica campestris* and *Triticum aestivum.* Chandra Babu and Kandasamy (1997) also reported that leachate of fresh leaf cuttings of eucalyptus tree had growth inhibitory effect on Bermuda grass than the leachate of dried leaves of eucalyptus. Khan et al. (2005) investigated the allelopathic potential of aqueous extracts of *Prosopis juliflora* leaves and *Eucalyptus camaldulensis* and bark of *Acacia nilotica*. The results showed that the germination percentage, seedling length (mm) and biomass yield (mg) $plant^{-1}$ of *Ipomoea* sp., *Asphodelus tenuifolius*, *Brassica campestris* and *Triticum aestivum* were significantly affected by tree extracts as compared to control.

4.5 Number of branches $plant^{-1}$

Significant variations were found for branches $plant^{-1}$ at harvest (Appendix IV). The highest number of branches $plant^{-1}$ (5.17) was obtained from the biomass of BARI sarisha13 which was incorporated with soil during sowing time of lentil (T_8) that statistically identical with T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9 and T_{10}. The lowest number of branches $plant^{-1}$ (3.83) was found from the water extract of BARI sarisha15 which was sprayed at 30 and 60 DAS of lentil (T_{11}) that statistically at par with T_1, T_2, T_3, T_4, T_5, T_6, T_7 and T_{10} (Figure 5).

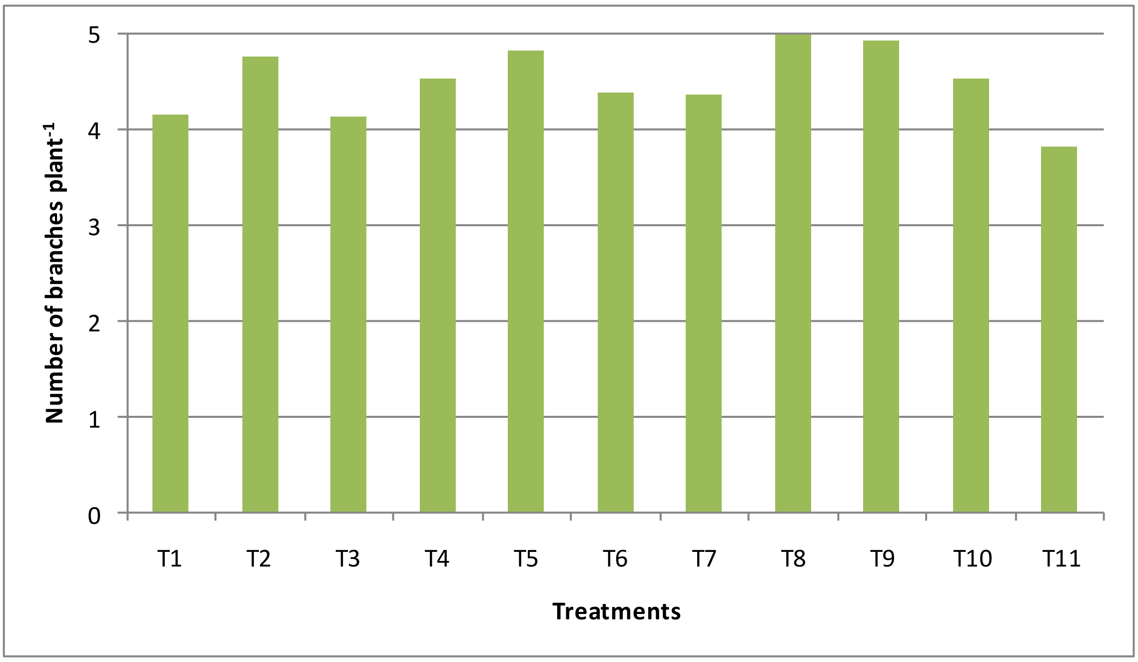
Mansoor *et al*. (2004) stated that water extracts of sorghum, Eucalyptus and Acacia were used in comparison with hand weeding and pre-emergence herbicide. All the treatments significantly affected number of branches/plant, number of pods/plant, 1000 grain weight and grain yield. Application of water extract of

Acacia ranked at the top in yield and almost all the yield components followed by two hand weeding + Pre-emergence herbicide treatments.



T_1=Control, T_2=Tori 7-Biomass incorporated @ 2.6 t ha^{-1} at sowing**,** T_3=Tori 7–Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil**,** T_4=BARI Sarisha 8–Biomass incorporated @ 2.6 t ha^{-1} at sowing**,** T_5=BARI Sarisha 8-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil**,** T_6=BARI Sarisha 11-Biomass incorporated @ 2.6 t ha^{-1} at sowing**,** T_7=BARI Sarisha 11-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil**,** T_8=BARI Sarisha 13–Biomass incorporated@ 2.6 t ha^{-1} at sowing, T_9=BARI Sarisha 13-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil**,** T_{10}=BARI Sarisha 15 –Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_{11}=BARI Sarisha15-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil

Figure 4. Effect of *Brassica* biomass and water extract on plant dry weight of lentil (SE=0.00, 0.03, 0.21 and 0.13 for 30, 60, 80 DAS and at harvest)



T_1=Control, T_2=Tori 7-Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_3=Tori 7–Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_4=BARI Sarisha 8–Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_5=BARI Sarisha 8-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_6=BARI Sarisha 11-Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_7=BARI Sarisha 11-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_8=BARI Sarisha 13–Biomass incorporated@ 2.6 t ha^{-1} at sowing, T_9=BARI Sarisha 13-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_{10}=BARI Sarisha 15 –Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_{11}=BARI Sarisha15-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil

Figure 5. Effect of *Brassica* biomass and water extract of on branches plant^{-1} of lentil (SE=0.37 at harvest)

4.6 Number of pods plant^{-1}

Significant variations were found for number of pods plant^{-1} at at harvest (Appendix IV). The highest number of pods plant^{-1} (71.70) was obtained from the biomass of BARI sarisha15 which was incorporated with soil during the sowing time of lentil (T_{10}) that differed with other treatments. The lowest number of pods plant^{-1} (33.53) was found from the water extract of Tori7 which was sprayed at 30 and 60 DAS of lentil (T_3) that differed with other treatments (Figure 6).

These results were similar with the findings of Mansoor *et al*. (2004) who stated that water extracts of sorghum,eucalyptus and acacia were significantly affected the number of branches plant^{-1}, number of pods plant^{-1}, 1000 grain weight and grain yield of mungbean.

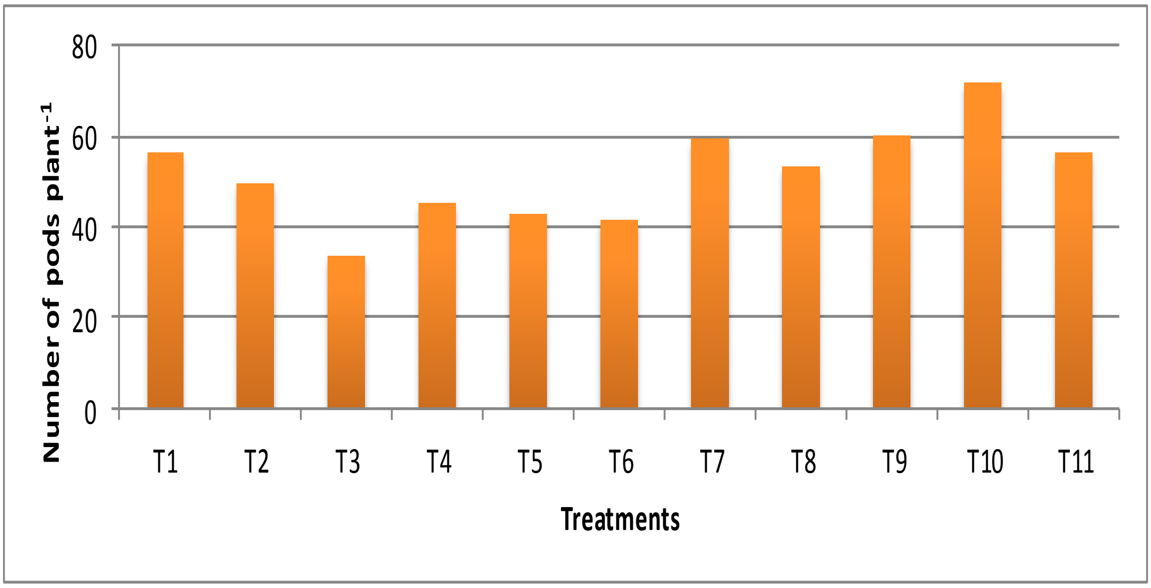


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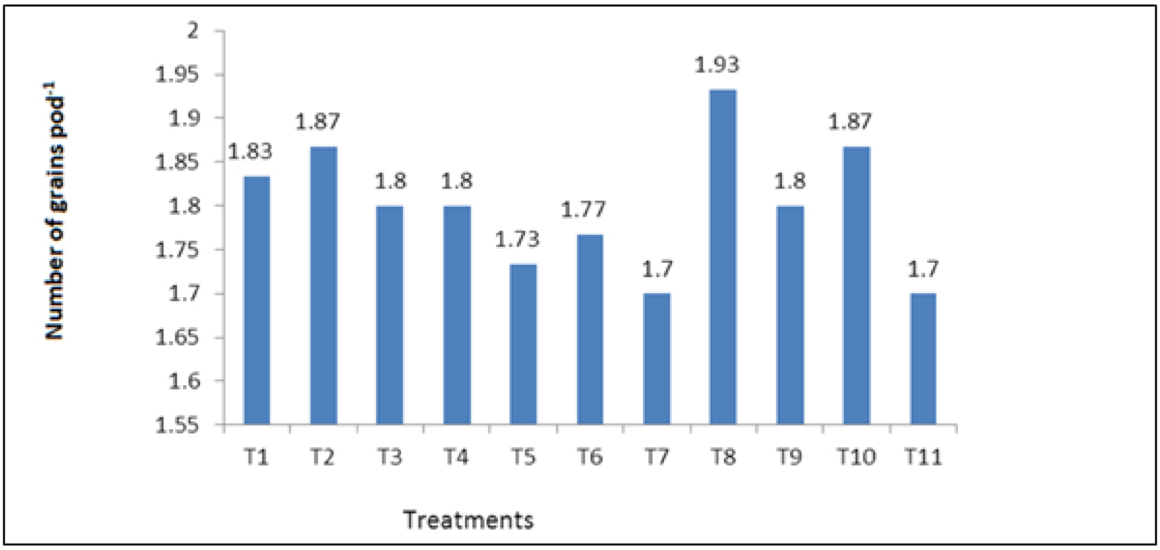
Figure 6. Effect of *Brassica* biomass and water extract on the pod number of lentil (SE=2.18 at harvest)

4.7 Number of grains pod^{-1}

Significant variations were found in number of grains pod^{-1} of lentil at harvest (Appendix IV). The highest number of grains pod^{-1} (1.93) was obtained from the biomass of BARI sarisha13 which was incorporated with soil during sowing time of lentil (T_8) that statistically similar with T_1, T_2, T_3, T_4, T_5, T_6, T_9 and T_{10}. The lowest number of grains pod^{-1} (1.70) was found from the water extract of BARI sarisha11 which was sprayed at 30 and 60 DAS of lentil (T_7) and the water extract of BARI sarisha15 that sprayed at 30 and 60 DAS of lentil (T_{11}) which was statistically at par with T_1, T_2, T_3, T_4, T_5, T_6, T_9 and T_{10} (Figure 7).

These results were similar with the findings of Mansoor *et al*. (2004) who stated that water extracts of sorghum, eucalyptus and acacia were significantly affected the number of branches plant^{-1}, number of pods plant^{-1}, 1000 grain weight and grain yield of mungbean.



T_1=Control, T_2=Tori 7-Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_3=Tori 7–Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_4=BARI Sarisha 8–Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_5=BARI Sarisha 8-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_6=BARI Sarisha 11-Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_7=BARI Sarisha 11-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_8=BARI Sarisha 13–Biomass incorporated@ 2.6 t ha^{-1} at sowing, T_9=BARI Sarisha 13-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_{10}=BARI Sarisha 15 –Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_{11}=BARI Sarisha15-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil

Figure 7.Effect of *Brassica* biomass and water extract on number of grains pod^{-1} of lentil (SE=0.08 at harvest)

4.8 1000 grains weight

After sun drying 1000 grains weight were taken from each treatment. There were significant variations observed for 1000 grains weight of lentil for respective treatments (Appendix V). The highest 1000 grains weight (20.37g) was measured from the biomass of BARI sarisha13 which was incorporated with soil during sowing time of lentil (T_8) that statistically similar with T_1, T_4, T_5, T_6 and T_9. The lowest 1000 grains weight (18.07g) was found from the water extract of Tori-7 which was sprayed at 30 and 60 DAS of lentil (T_3) that statistically at par with T_2, T_6, T_7, T_{10} and T_{11} (Figure 8). These results were similar with the findings of Mansoor *et al*. (2004) who stated that water extracts of sorghum, eucalyptus and acacia were significantly affected the number of branches plant^{-1}, number of pods plant^{-1}, 1000 grain weight and grain yield of mungbean.

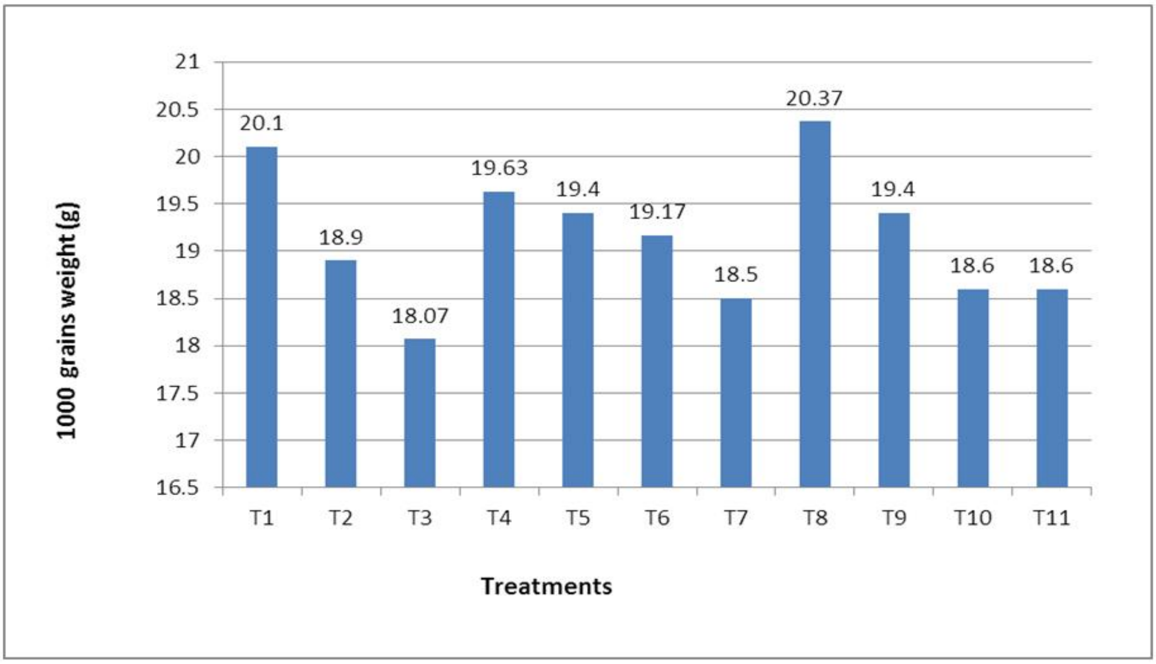


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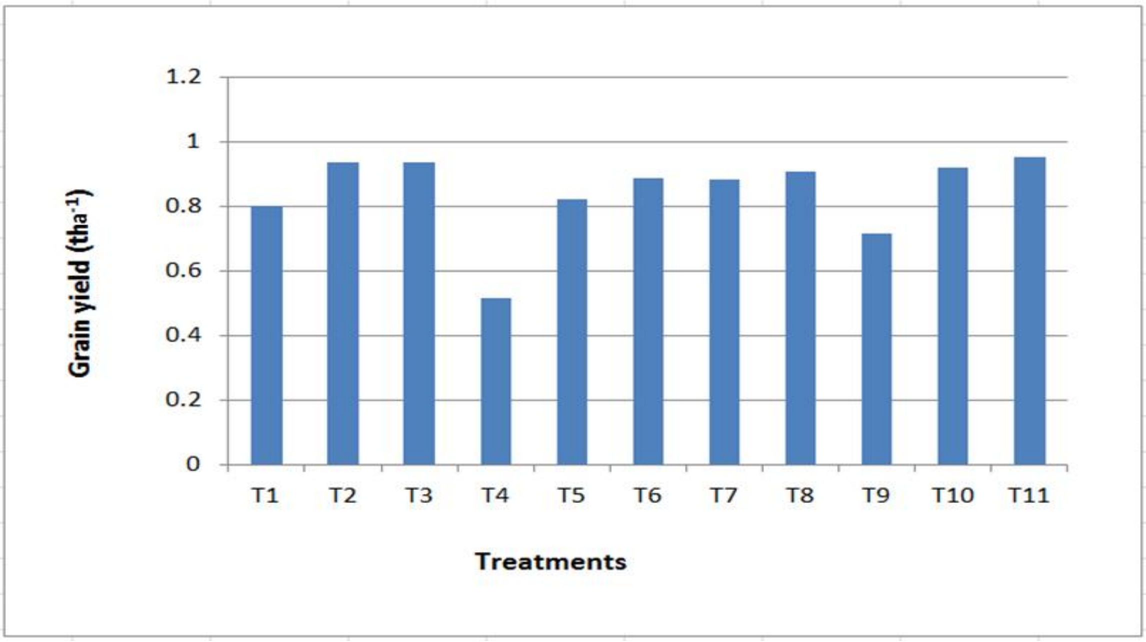
Figure 8. Effect of *Brassica* biomass and water extract on 1000 grains weight of lentil (SE=0.45 at harvest)

4.9 Grain yield

After sun drying grain yield were taken from each treatment. There were significant variations observed for grain yield (Appendix V).

The highest grain yield (0.95tha^{-1}) was obtained from the water extract of BARI sarisha15 which was sprayed at 30 and 60 DAS of lentil (T_{11}) that statistically identical with T_2, T_3, T_8 and T_{10}. The lowest grain yield (0.52 t ha^{-1}) was found from the biomass of BARI sarisha8 which was incorporated with soil during sowing time of lentil (T_4) that statistically differed with other treatments (Figure 9). Similar results also obtained by Naseem *et al*. (2009) who showed that inhibitory effects of sunflower plant water extract increased with increasing the water extract application frequency and increased the wheat yield significantly over control. These results were also in agreement with the findings of Cheema *et al.* (2003b) who noted that concentrated sunflower water extract @ 12 L ha^{-1} sprayed at 30 and 40 days after sowing gave consistently better weed control and increased wheat yield by 5.5% over control.



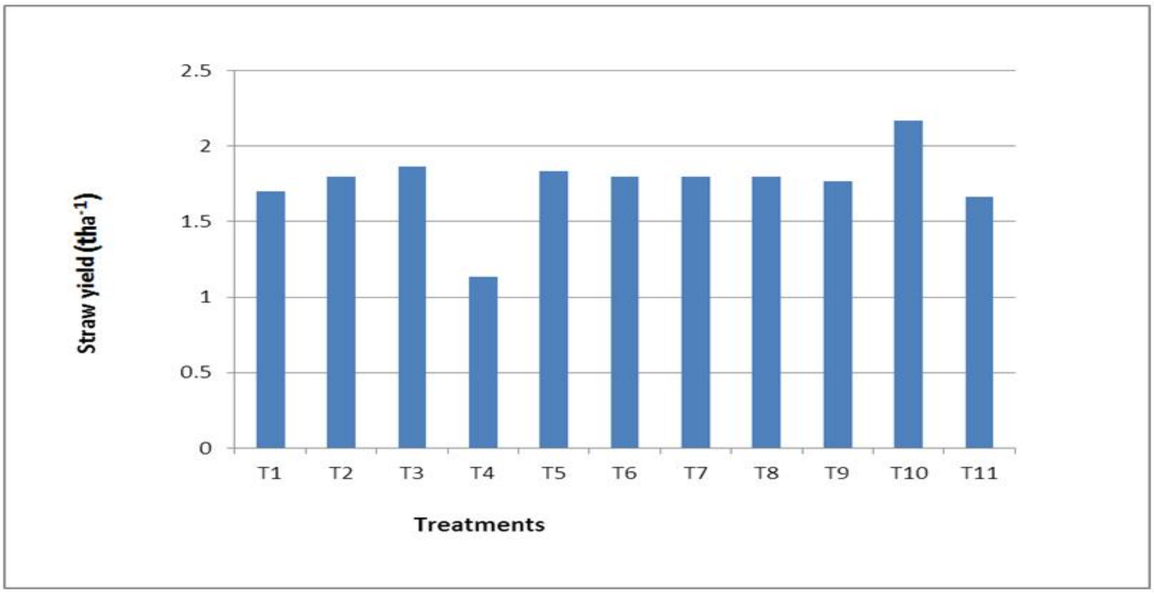
T_1=Control, T_2=Tori 7-Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_3=Tori 7–Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_4=BARI Sarisha 8–Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_5=BARI Sarisha 8-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_6=BARI Sarisha 11-Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_7=BARI Sarisha 11-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_8=BARI Sarisha 13–Biomass incorporated@ 2.6 t ha^{-1} at sowing, T_9=BARI Sarisha 13-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_{10}=BARI Sarisha 15 –Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_{11}=BARI Sarisha15-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil

Figure 9. Effect of *Brassica* biomass and water extract on grain yield of lentil (SE=0.02 at harvest)

4.10 Straw yield

After sun drying straw yield were taken from each treatment. There were significant variations observed for straw yield (Appendix V).

The highest straw yield (2.17 t ha^{-1}) was found from the biomass of BARI sarisha15 which was incorporated with soil during sowing time of lentil (T_{10}) which was statistically differed with other treatments. The lowest straw yield (1.13tha^{-1}) was found from the biomass of BARI sarisha8 which was incorporated with soil during sowing time of lentil (T_4) that also differed with other treatments (Figure 10). Cheema *et al.* (1997) reported that the application of sorghum (*Sorghum bicolor*) and sunflower (*Helianthus annuus*) water extracts reduced weed biomass by 33-53% and increased in wheat yield by 7-14%.

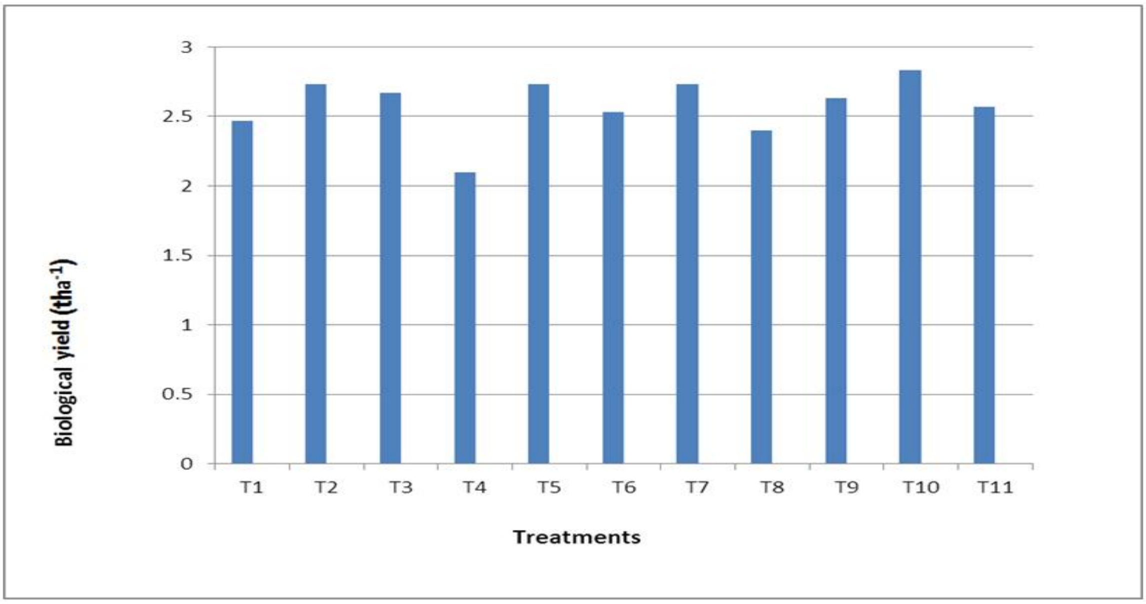


T_1=Control, T_2=Tori 7-Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_3=Tori 7–Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_4=BARI Sarisha 8–Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_5=BARI Sarisha 8-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_6=BARI Sarisha 11-Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_7=BARI Sarisha 11-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_8=BARI Sarisha 13–Biomass incorporated@ 2.6 t ha^{-1} at sowing, T_9=BARI Sarisha 13-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_{10}=BARI Sarisha 15 –Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_{11}=BARI Sarisha15-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil

Figure 10. Effect of *Brassica* biomass and water extract on straw yield of lentil (SE=0.04 at harvest)

4.11 Biological yield

There were significant variations observed for biological yield (Appendix VI). The highest biological yield (2.83tha^{-1}) was measured from the biomass of BARI sarisha15 which was incorporated with soil during sowing time of lentil (T_{10}) that statistically similar with T_2, T_3, T_5, T_6, T_7, T_9, T_{10} and T_{11}. The lowest biological yield (2.10tha^{-1}) was found from the biomass of BARI sarisha8 which was incorporated with soil during sowing time of lentil (T_4) that statistically at par with T_8 (Figure11).

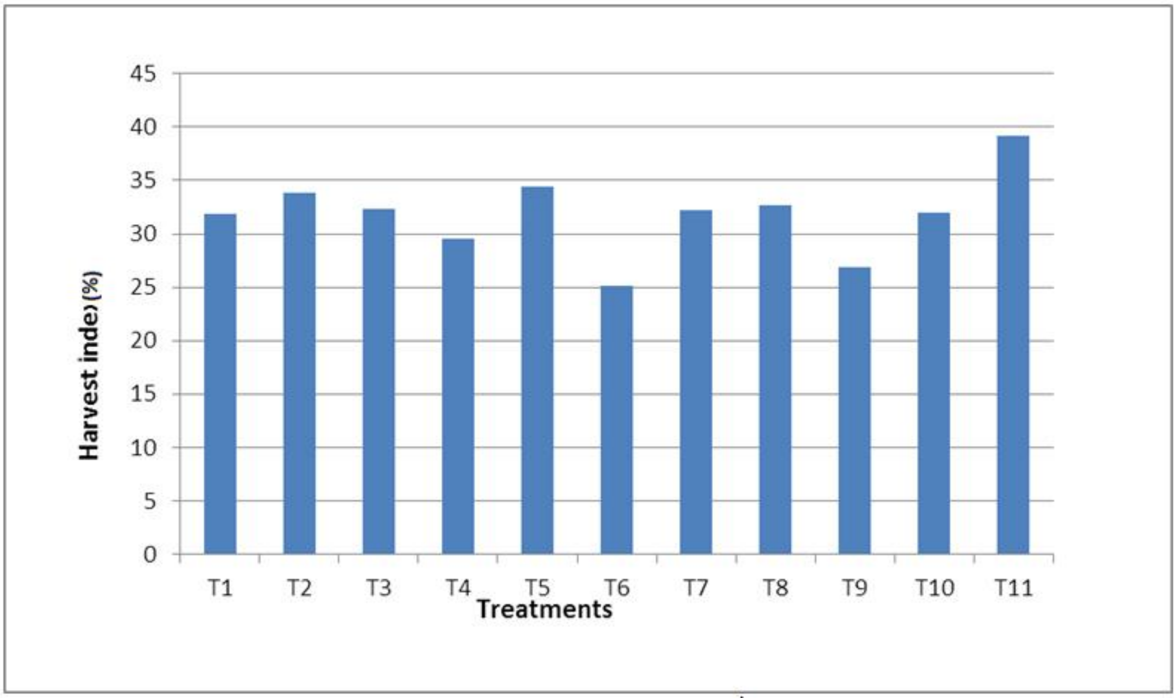


T_1=Control, T_2=Tori 7-Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_3=Tori 7–Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_4=BARI Sarisha 8–Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_5=BARI Sarisha 8-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_6=BARI Sarisha 11-Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_7=BARI Sarisha 11-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_8=BARI Sarisha 13–Biomass incorporated@ 2.6 t ha^{-1} at sowing, T_9=BARI Sarisha 13-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_{10}=BARI Sarisha 15 –Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_{11}=BARI Sarisha15-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil

Figure 11. Effect of *Brassica* biomass and water extract on biological yield of lentil (SE=0.10 at harvest)

4.12 Harvest index

Significant variations were found for harvest index of lentil (Appendix VI). The highest harvest index (39.23%) was obtained from the water extract of BARI sarisha15 which was sprayed at 30 and 60 DAS of lentil (T_{11})) which was differed with other treatments. The lowest harvest index (25.17%) was found from the biomass of BARI sarisha11 which was incorporated with soil during sowing time of lentil (T_6) that statistically similar with T_9 (Figure12).

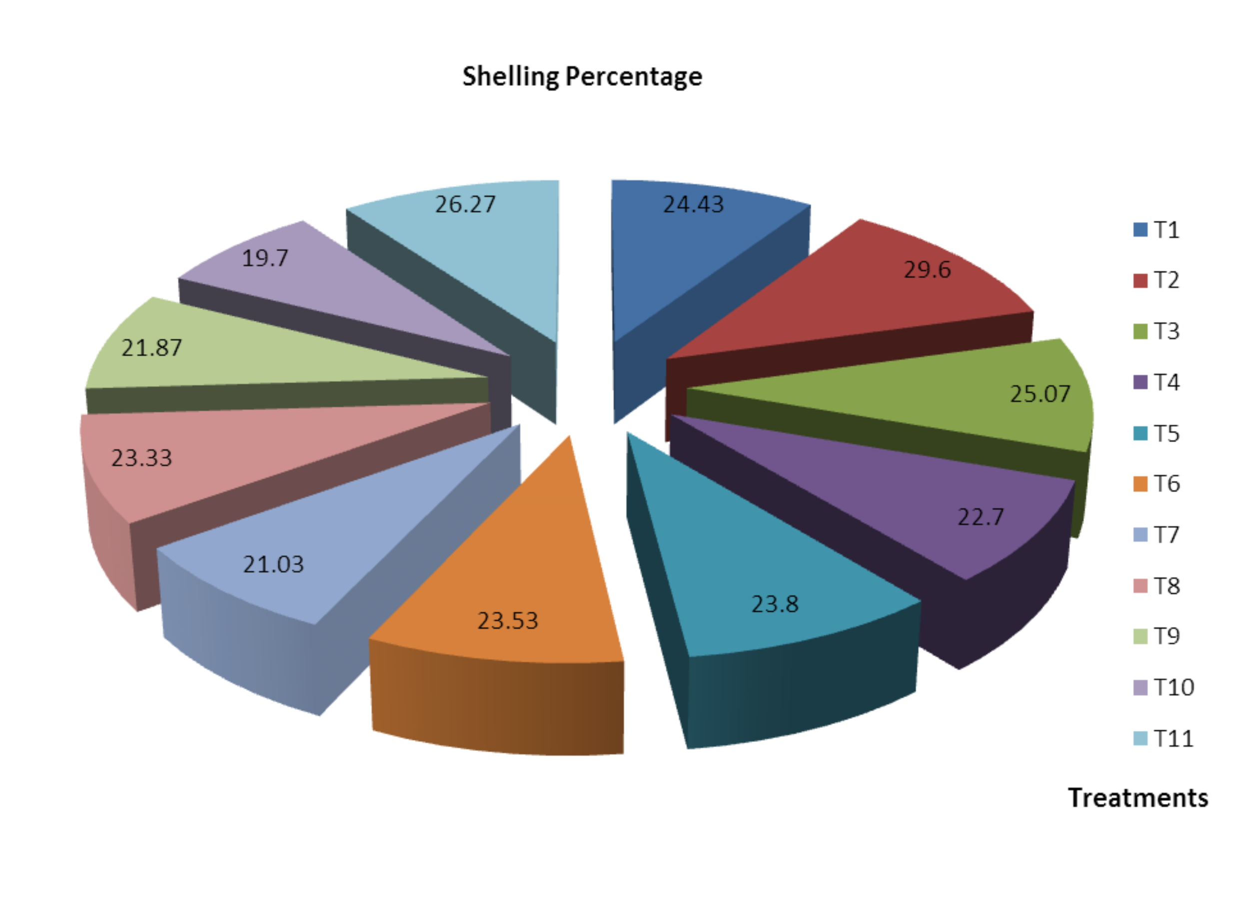


T_1=Control, T_2=Tori 7-Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_3=Tori 7–Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_4=BARI Sarisha 8–Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_5=BARI Sarisha 8-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_6=BARI Sarisha 11-Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_7=BARI Sarisha 11-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_8=BARI Sarisha 13–Biomass incorporated@ 2.6 t ha^{-1} at sowing, T_9=BARI Sarisha 13-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_{10}=BARI Sarisha 15 –Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_{11}=BARI Sarisha15-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil

Figure 12. Effect of *Brassica* biomass and water extract on harvest index of lentil (SE=0.69 at harvest)

4.13 Shelling percentage

There were significant variations observed for shelling percentage of lentil (Appendix VI). The highest shelling percentage (29.60%) was obtained from the biomass of Tori7 which was incorporated with soil during sowing time of lentil (T_2) that differed with other treatments. The lowest shelling percentage (19.70%) was found from the biomass of BARI sarisha15 which was incorporated with soil during sowing time of lentil (T_{10}) that statistically similar with T_7 (Figure 13).



T_1=Control, T_2=Tori 7-Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_3=Tori 7–Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_4=BARI Sarisha 8–Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_5=BARI Sarisha 8-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_6=BARI Sarisha 11-Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_7=BARI Sarisha 11-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_8=BARI Sarisha 13–Biomass incorporated@ 2.6 t ha^{-1} at sowing, T_9=BARI Sarisha 13-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil, T_{10}=BARI Sarisha 15 –Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_{11}=BARI Sarisha15-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil

Figure 13. Effect of *Brassica* biomass and water extract on shelling percentage of lentil (SE=0.56 at harvest)

CHAPTER 5

SUMMARY AND CONCLUSION

The present piece of work was conducted at the Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka from November, 2011 to March, 2012 to find out the allelopahtic effect of *Brassica* varieties on weed control and yield of lentil. There were eleven sets of treatments in the experiment. The treatment of the experiment consisted green *Brassica* biomass and water extract of dry *Brassica* biomass. Green *Brassica* biomass (30 days old) was incorporated in the soil at the sowing time of lentil @ 2.6 t ha^{-1} (2kg/plot). Extracted water of dry *Brassica* biomass of each variety were sprayed two times (30 & 60 DAS of lentil) in the specific plot @ 1.3 t 6666 L^{-1} water ha^{-1} (1kg/5 lit. /plot). The treatments were, T_1=Control(No biomass or no spray), T_2=Tori 7-Biomass incorporated @ 2.6 t ha^{-1} at sowing**,** T_3=Tori 7-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil**,** T_4=BARI Sarisha 8-Biomass incorporated @ 2.6 t ha^{-1} at sowing**,** T_5=BARI Sarisha 8-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil**,** T_6=BARI Sarisha 11-Biomass incorporated @ 2.6 t ha^{-1} at sowing**,** T_7=BARI Sarisha 11-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil**,** T_8=BARI Sarisha 13-Biomass incorporated @ 2.6 t ha^{-1} at sowing, T_9=BARI Sarisha 13-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil**,**T_{10}=BARI Sarisha 15-Biomass incorporated @ 2.6 t ha^{-1} at sowing,T_{11}=BARI Sarisha 15-Dry matter water extract sprayed @ 1.3 t 6666 L^{-1} water ha^{-1} at 30 and 60 DAS of lentil

The experiment was laid out in a completely randomized block design following the principles of randomization with three replications. The sowing date of lentil was on 30th October, 2012. The unit plot size was 3 m × 2.5 m = 7.5 m^2. Lentil was harvested at 10th March, 2013.

Observations were made on lentil as weed population, dry matter weight of weeds, plant height, dry matter weight $plant^{-1}$, days to maturity, number of branches $plant^{-1}$, number of pods $plant^{-1}$, number of grains pod^{-1}, weight of 1000 grains, grain yield, straw yield, biological yield, harvest index, shelling percentage. One square meter area were randomly selected from each unit plot for taking observations on weed population at 30 days after sowing and 60 days after sowing, dry weight of weed at 30 days after sowing and 60 days after sowing. Ten (10) plants were randomly selected $plot^{-1}$ for taking plant height and dry weight $plant^{-1}$ data at 30, 60 and 80 DAS and at harvest. At harvest, ten (10) plants $plot^{-1}$ were selected randomly leaving the harvest area from which number of branches $plant^{-1}$, number of pods $plant^{-1}$, number of grains pod^{-1} data were calculated. Thousand grains were counted from the seed sample and weighed at 12% moisture level using an electric balance and recorded as per. An area of 3.75 m^2 (Inner five rows) from each plot was harvested. After threshing, proper drying and cleaning, the grain yield and straw yield of each sample plot was weighed and values were converted to tha^{-1}. Biological yield was determined by adding grain yield and straw yield of the harvest area (Biological yield = Grain yield + straw yield). Harvest index (%) was determined by dividing the economic (grain) yield by the biological yield from the same area (Gardner *et al.* 1985) and multiplying by 100. Shelling percentage (%) was determined through dividing the seed weight by pod weight and multiplying by 100.

Green *Brassica* biomass and water extract of dry *Brassica* biomass influenced weed population, dry matter weight of weeds, plant height, dry matter weight plant^{-1} , days to maturity, number of branches plant^{-1}, number of pods plant^{-1}, number of grains pod^{-1}, weight of 1000 grains, grain yield, straw yield, biological yield, harvest index, shelling percentage.

The highest no. of weeds m^{-2} both at 30 and 60 DAS were observed in treatment T_1 (164.00 and 169.00 respectively) and lowest in T_2 (62.00) and T_7 (70.00) while highest dry weight of weeds m^{-2} both at 30 and 60 DAS were found in treatment T_1 (4.80g and 16.10g respectively) and minimum in T_9 (1.17g) and T_2 (6.63g) respectively. At harvest the maximum plant height (34.81cm) and dry weight plant^{-1} (3.83g) were found in treatment T_{11} and T_7 and minimum in T_5 (23.99cm) and T_6 (2.47g) respectively. The highest branches plant^{-1} (5.17), pods plant^{-1} (71.70), grains pod^{-1} (1.93), 1000 grains wt. (20.37g) were found in treatment T_8, $T_{10,}$ T_8 and T_8 respectively. But the lowest similar branches plant^{-1} (3.83), pods plant^{-1} (33.53), grains pod^{-1} (1.70), 1000 grains wt. (18.07g) were found in treatment T_{11}, $T_{3,}$ T_7 and T_2 respectively. There was a significant result on biological yield, grain yield, straw yield, harvest index and shelling percentage. The highest similar biological yield (2.83 t ha^{-1}), grain yield (0.952.83 t ha^{-1}), straw yield (2.17 t ha^{-1}), harvest index (39.23%) and shelling percentage (29.60%) were observed in treatment T_{10}, T_{11}, T_{10}, T_{11} and T_2 respectively. The lowest similar biological yield (2.10 t ha^{-1}), grain yield (0.52 t ha^{-1}), straw yield (1.13 t ha^{-1}), harvest index (25.17%) and shelling percentage (19.70 %) were found in treatment T_4, T_4, T_4, T_6 and T_{10} respectively.

In short, the land with no biomass application encouraged growth of weed and dry weight of weed that means *Brassica* biomass reduced weed growth in all cases of application. Weed control was quite positive with application *of Brassica* biomass as well as spraying of *Brassica* dry matter water extract.

However, to reach a specific recommendation, more research work on wider range of allelopathic effect of *Brassica* biomass on weed management and yield of lentil should be done over different Agro-ecological zones.

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APPENDICES

Appendix I. Mean square values of weed population and dry matter at different stages

Sources of variation	Degrees of freedom	Weed population at		Weed dry matter at	
		30 DAS	60 DAS	30 DAS	60 DAS
Replication	2	79.121	36.485	0.022	0.064
Treatment	10	3335.388*	3245.273*	3.856*	31.754*
Error	20	18.488	17.218	0.010	0.235

Appendix II. Mean square values of plant height at different stages

Sources of variation	Degrees of freedom	Plant height at			
		30 DAS	60 DAS	80 DAS	101 DAS
Replication	2	1.652	2.491	10.989	6.853
Treatment	10	1.384*	0.840*	11.879*	20.839*
Error	20	0.500	0.537	9.203	3.509

Appendix III. Mean square values of dry weight plant^{-1} at different stages

Sources of Variation	Degrees of freedom	Dry weight plant^{-1} at			
		30 DAS	60 DAS	80 DAS	101 DAS
Replication	2	0.000	0.005	0.094	0.035
Treatment	10	0.000^{NS}	0.030*	0.109*	0.590*
Error	20	0.000	0.003	0.138	0.054

^{NS}= Non Significant

*= Significant @ 5% Level of Probality

Appendix IV. Mean square values of number of branches plant^{-1}, number of pods plant^{-1}, number of grains pod^{-1} at harvest

Sources of variation	Degrees of freedom	Number of branches plant^{-1}	Number of pods plant^{-1}	Number of grains pod^{-1}
Replication	2	0.268	12.366	0.001
Treatment	10	0.460*	352.638*	0.016*
Error	20	0.420	14.241	0.017

Appendix V. Mean square values of 1000 grains weight, grain yield, straw yield at harvest

Sources of variation	Degrees of freedom	1000 grains weight	Grain yield	Straw yield
Replication	2	0.446	0.000	0.001
Treatment	10	1.501*	0.051*	0.178*
Error	20	0.612	0.001	0.005

Appendix VI. Mean square values of biological yield, harvest index, shelling percentage at harvest

Sources of variation	Degrees of freedom	Biological yield	Harvest index	Shelling percentage
Replication	2	0.034	4.888	1.299
Treatment	10	0.127*	42.479*	21.423*
Error	20	0.033	1.430	0.950

^{NS}= Non Significant

*= Significant @ 5% Level of Probality

PLATES

Plate 1. Field view of *Brassica* at early stage

Plate 2. Field view of *Brassica* at vegetative stage

Plate 3. Harvested *Brassica* (Tori 7)

Plate 4. Harvested *Brassica* (BARI Sarisha 8)

Plate 5. Harvested *Brassica* (BARI Sarisha 11)

Plate 6. Harvested *Brassica* (BARI Sarisha 13)

Plate 7. Harvested *Brassica* (BARI Sarisha 15)

Plate 8. Field view of experiment at sowing

Plate 9. Field view of experiment at sowing

Plate 10. Field view of experiment at sowing

Plate 11. Soaking condition of dry *Brassica* biomass

Plate 12. Water extract of dry *Brassica* biomass

Plate 13. Collecting data of the experiment at vegetative stage

Plate 14. Field view of the experiment at vegetative stage

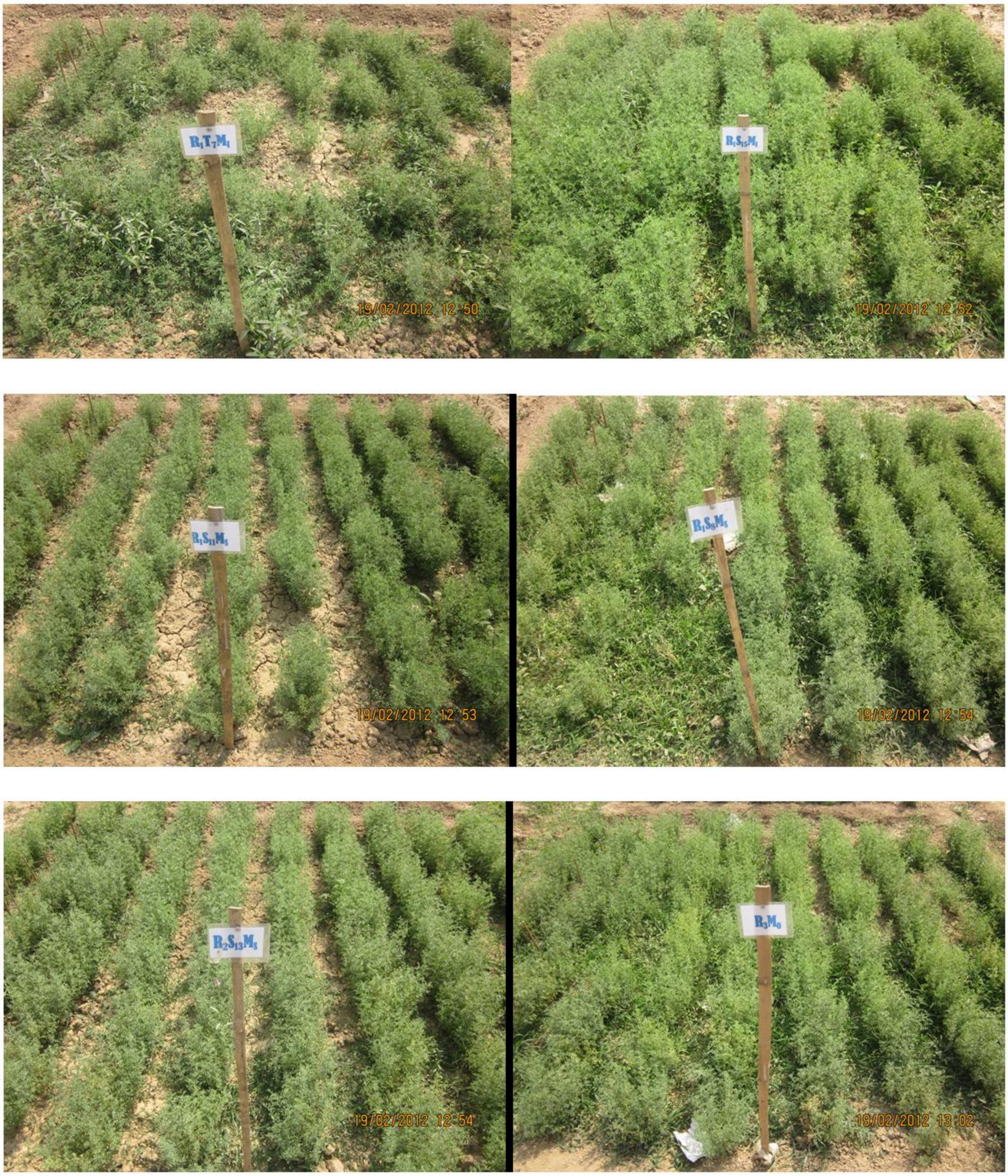

Plate 15. Variation of weed status in different treatments