EFFICACY OF *BRASSICA* VARIETIES TO CONTROL WEEDS IN WHEAT

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EFFICACY OF *BRASSICA* VARIETIES TO CONTROL WEEDS IN WHEAT

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CERTIFICATE

This is to certify that the thesis entitled **"EFFICACY OF *BRASSICA* VARIETIES TO CONTROL WEEDS IN WHEAT"** 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 ***RATINA CHAKMA,*** Registration. No. 06-2145, 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.

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The Author

EFFICACY OF *Brassica* VARIETIES TO CONTROL WEEDS IN WHEAT

ABSTRACT

The experiment was conducted at the Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka from October, 2011 to March, 2012 to find out the efficacy of *Brassica* varieties to control weeds in wheat. The experiment was conducted in completely randomized block design with three replications. The experiment consisted of 12 treatments T_1 : No *Brassica* + no biomass (Control), T_2 : No *Brassica* + biomass of 5 varieties , T_3 : *Brassica* (Tori 7) without biomass, T_4 : *Brassica* (Tori 7) with biomass of same variety, T_5 : *Brassica* (BARI sarisha - 8) without biomass, T_6 : *Brassica* (BARI sarisha - 8) with biomass of same variety , T_7 : *Brassica* (BARI sarisha - 11) without biomass, T_8 : *Brassica* (BARI sarisha - 11) with biomass of same variety, T_9 : *Brassica* (BARI sarisha - 13) without biomass , T_{10} : *Brassica* (BARI sarisha - 13) biomass of same variety, T_{11} : *Brassica* (BARI sarisha - 15) without biomass, T_{12} : *Brassica* (BARI sarisha - 15) with biomass of same variety. Results revealed that T_1 treatment (no *Brassica* + no biomass) resulted the highest weed population at 30 DAS (days after sowing) (230.80 m^{-2}) and at 60 DAS (300.70 m^{-2}). On the other hand T_6 treatment (BARI Sarisha-8 + biomass) resulted the lowest weed population at 30 DAS (100.40 m^{-2}) and at 60 DAS (181.30) m^{-2} which was statistically similar with other *Brassica* crop with biomass treated plots. The highest dry weight of weed in wheat field was observed in T_1 treatment (no *Brassica* + no biomass) at 30 DAS and (29.14 g m^{-2}) and 60 DAS (57.51 g $m^{-2)}$. At 30 DAS the lowest dry weight of weed (8.33 gm^{-2}) in wheat field was observed in T_6 treatment, while at 60 DAS the lowest weed dry weight (22.98 g m^{-2}) recorded from T_{12} treatment, which was statistically similar with other *Brassica* biomass treated plots. The highest number of effective tiller (42.67 m^{-1}) and highest grain yield was found from T_{12} treatment (1.75 t ha^{-1}) whereas, the lowest number of effective tiller (32.67 m^{-1}) and the lowest grain yield (1.36 t ha^{-1}) was found from T_1 treatment. It appeared from the above results that, weed population did not differ for varietal effect but varied for biomass irrespective of variety. Incorporation of *Brassica* biomass reduced 35% and 21% weed population in wheat field compared to that of T_1 (no *Brassica* crop and no *Brassica* biomass). It was also observed that the T_1 treatment resulted 19%, 20% and 21% lower wheat grain yield compared to $T_{8,}$ T_6 and T_{12} respectively. So, the treatments containing *Brassica* crop with *Brassica* biomass of the same variety not only controlled weed in the wheat field but also encouraged yield contributing characters of wheat and gave higher grain yield than the treatments containing no *Brassica* and no *Brassica* biomass.

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CHAPTER 1

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the most important cereal crop in the world as well as in Bangladesh that provides about 20 % of total food calories. About two third of the total world's population consume wheat as staple food (Majumder, 1991). It contains carbohydrate (78.1%), protein (14.7%), minerals (2.1%), fat (2.1%) and considerable proportion of vitamins (Peterson, 1965). The crop is grown under different environmental condition ranging from humid to arid, subtropical to temperate zone (Saari, 1998).

In Bangladesh, it covers 400,000 hectares of land with an annual production of 737,000 metric tons (BBS, 2008). In the Market Year 2012-13 Bangladesh wheat crop (planted in November/December and harvested in March/April) is estimated at 1.15 million tons from 410,000 hectares of land (BGFA, 2013). While wheat area has increased in response to high prices, the growing scarcity of water for irrigation has prompted farmers to shift some Boro rice growing areas to wheat. While wheat only accounts for about 12 percent of total cereal consumption, it is the second most important staple food in Bangladesh after rice. The wheat growing season overlaps with Boro rice and other remunerative crops like corn, potato, and winter vegetables. However, wheat cultivation remains a preferred option particularly for non-irrigated land with low input -use.

Though wheat is an important cereal crop in Bangladesh, the average yield 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, wheat 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. There are many factors responsible for low yield, of which weed, the natural enemy of wheat that reduces its yield if not properly controlled. The yield reduction of wheat by weed is reported to be 20 - 30 % (Turk and Tawaha, 2002). Controlling weeds by mechanical means or by using herbicide is uneconomic due to labour shortage and environmental hazards respectively. Managing croplands according to nature's principles (Allelopathy) 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. Allelopathy refers to a plant's ability to chemically inhibit the growth of other plants. 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; Rahman *et al*., 2012 a). 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%. As these residues decompose, weed suppression effect will also decline. Residues that are more layered and more compressed will be more suppressive.

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 wheat.

OBJECTIVES

Considering the above context the experiment was designed with the following objectives:

1. To find out the role of previous land condition on the weed status, growth and yield of wheat
2. To study the effect of 5 different *Brassica* biomass to control weeds in wheat field.
3. To find out the suitable variety of *Brassica* biomass to control weeds.

CHAPTER 2

REVIEW OF LITERATURE

Wheat is an important cereal crop that attracted less concentration in respect of various aspects than the high yielding boro rice. Wheat yield may be reduced significantly when weeds compete with wheat plants for light, water, and minerals. Weeds may also inhibit wheat growth through release of allelopathic chemicals that are toxic to wheat 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 wheat 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.* (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.

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 of pecan 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.* (2012 b) 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.

Kanchan and Jayachandra (1976) stated that there was a 30-40% reduction in yield of crop plants when grown on soil containing dried root and leaf material of *Parthenium*. Parthenin enters the soil through the decomposing leaf litter.

Kanchan (1975) and Kanchan and Jayachandra, (1980 a,b) identified various phenolic compounds in *Parthenium* (caffeic, vanillic, ferulic, chlorogenic and anisic acid) which may be responsible for growth reduction of test crops in amended soils.

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.* (2012a) noted that weed population and weed dry weight showed 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 glucosinolates 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, field pea, 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). Field pea 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.

Teasadale 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.

Alsaawadi *et al.* (1988) conducted a screening experiment to examine the activity of sorghum root exudates of 100 cultivars to inhibit germination and seedling development of Pig weed (*Amaranthus retroflexus*) in a sand culture medium. A high variability was observed in the ability of the test cultivars to alter seed germination and/or seedling growth of the weed. They found 82% of the control reduction in seed germination in 25 cultivars. They also found 10 cultivars inhibiting *A. retroflexus* growth by more than 79% of control.

2.2 Effect of Crop residue or 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.* (2012a) 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.* (2008 a) 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 Smetolachlor + 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 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 g m-2, respectively) than the control (49.47 g m-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.

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.

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 days 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.

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.

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.

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.

Om *et al.* (2002) listed the allelopathic effect of different weeds on *Phalaris minor* and tested the allelopathic potentiality as per 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%.

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-nunez (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 Effect of variety

2.3.1 Effect on growth characters

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.

2.3.2 Effect on yield and yield contributing 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.

2.3.3 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 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 mulchfree 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) reported that 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 presenting a brief description of the experimental site, soil, climate, experimental design, treatments, cultural operations and analysis of different parameters for both *Brassica* sp. and wheat under the following headings;

3.1 Location

The experiment was carried out during the Rabi season (October to March) of 2011-12, at 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 the 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 75-80 days to mature. Susceptible to leaf blight disease. Major insect is Brassica Aphid. Harvesting time January and potential seed yield is 1.6-2.0 t 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-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 and 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 Kustia, 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 is on 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. 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 wheat cultivar BARI gom-25

BARI gom-25 is a modern wheat variety released by Wheat Research Centre, BARI in 2010. The variety is semi-dwarf, early maturing and high yielding. Leaves are deep green and broad. It takes 57-61 days to heading. Spikes are long with 45-55 grains per spike. Grains are amber in colour, bright and larger in size (Thousand grain weight 54-58g). It shows moderate level of tolerance to heat stress giving 6-10% higher yield than Shatabdi under late seeding. There are very few hairs in the upper culm node. Glaucosity in the spike, culm and flag leaf sheath is medium dense. The shoulder of the lower glume of the spikelet is narrow and sloppy with short break (< 5.0 mm) with numerous spines. Sowing time November 15-30, Harvesting time March-April. Crop duration is 102-110 days. It can be grown under both optimum and late seeding conditions. Specially, suitable for growing well in southern region having salinity level of 8-10 dS/m at seedling stage. Highly tolerant to *Bipolaris* leaf blight and resistant to leaf rust diseases.

3.5 Experimental treatments

There were twelve setts of treatments in the experiment. The treatments are shown below;

T_1 : No *Brassica* + no biomass (Control),

T_2 : No *Brassica* + biomass of 5 varieties ,

T_3 : *Brassica* (Tori 7) without biomass,

T_4 : *Brassica* (Tori 7) with biomass of same variety,

T_5 : *Brassica* (BARI Sarisha - 8) without biomass,

T_6 : *Brassica* (BARI Sarisha - 8) with biomass of same variety ,

T_7 : *Brassica* (BARI Sarisha - 11) without biomass,

T_8 : *Brassica* (BARI Sarisha - 11) with biomass of same variety,

T_9 : *Brassica* (BARI Sarisha - 13) without biomass ,

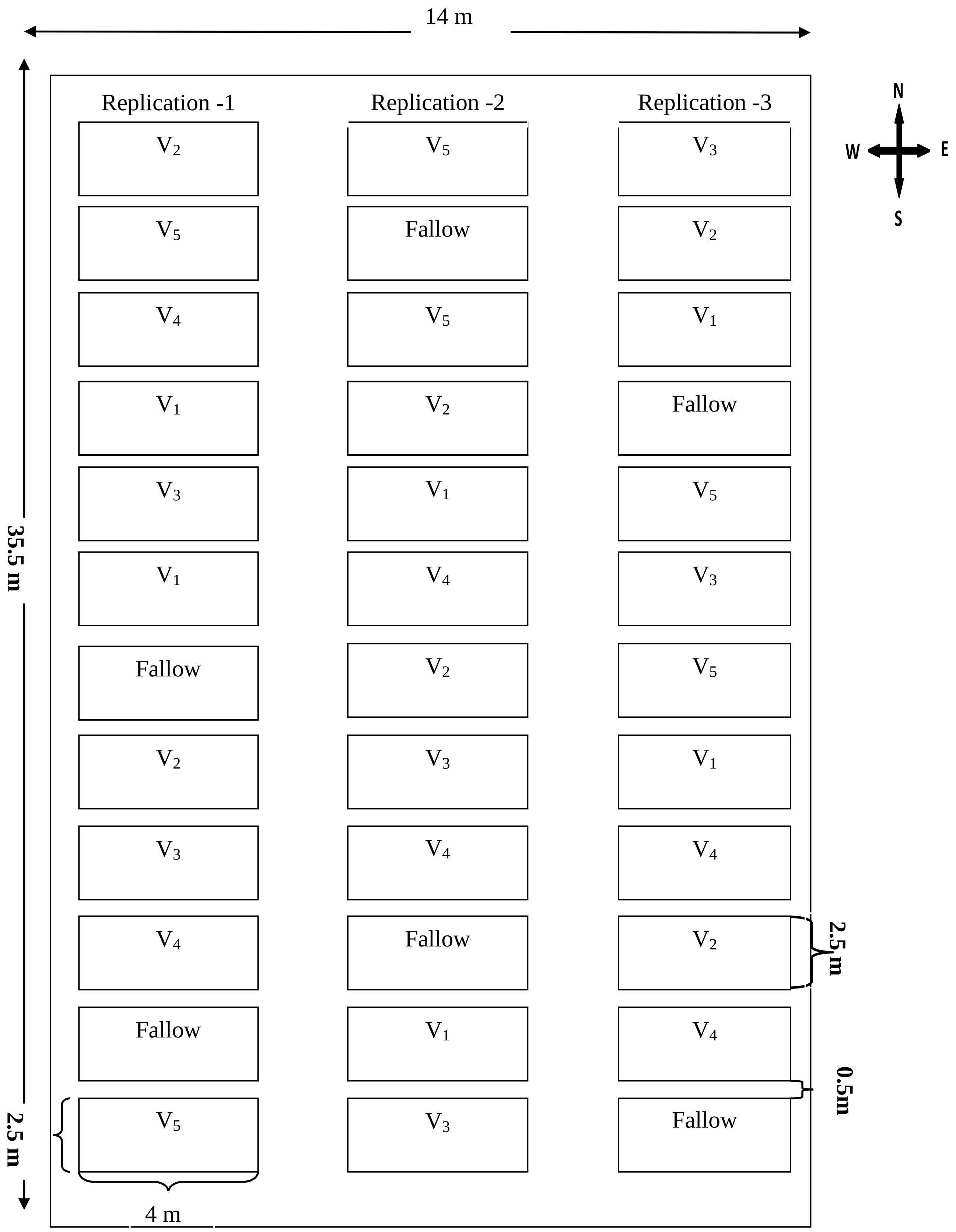
T_{10} : *Brassica* (BARI Sarisha - 13) with biomass of same variety,

T_{11} : *Brassica* (BARI Sarisha - 15) without biomass,

T_{12} : *Brassica* (BARI Sarisha - 15) with biomass of same variety.

3.6.1 Layout of *Brassica* spp.

The experimental unit was divided into three blocks. Each block was divided to in twelve main plots. Tori 7, BARI Sarisha 8, BARI Sarisha 11, BARI Sarisha 13, and BARI Sarisha 15 each of the variety was sown in 5×2=10 plots and rest two plots of each block were kept fallow. Sowing was done at 30th October. The plot was 2.5 m × 4m = 10 m^2 in size with 0.5 m distance between plots. The layout of the experiment is shown in Figure 1. The *Brassica* plants were uprooted on 29th November for incorporation in wheat field as per treatments.

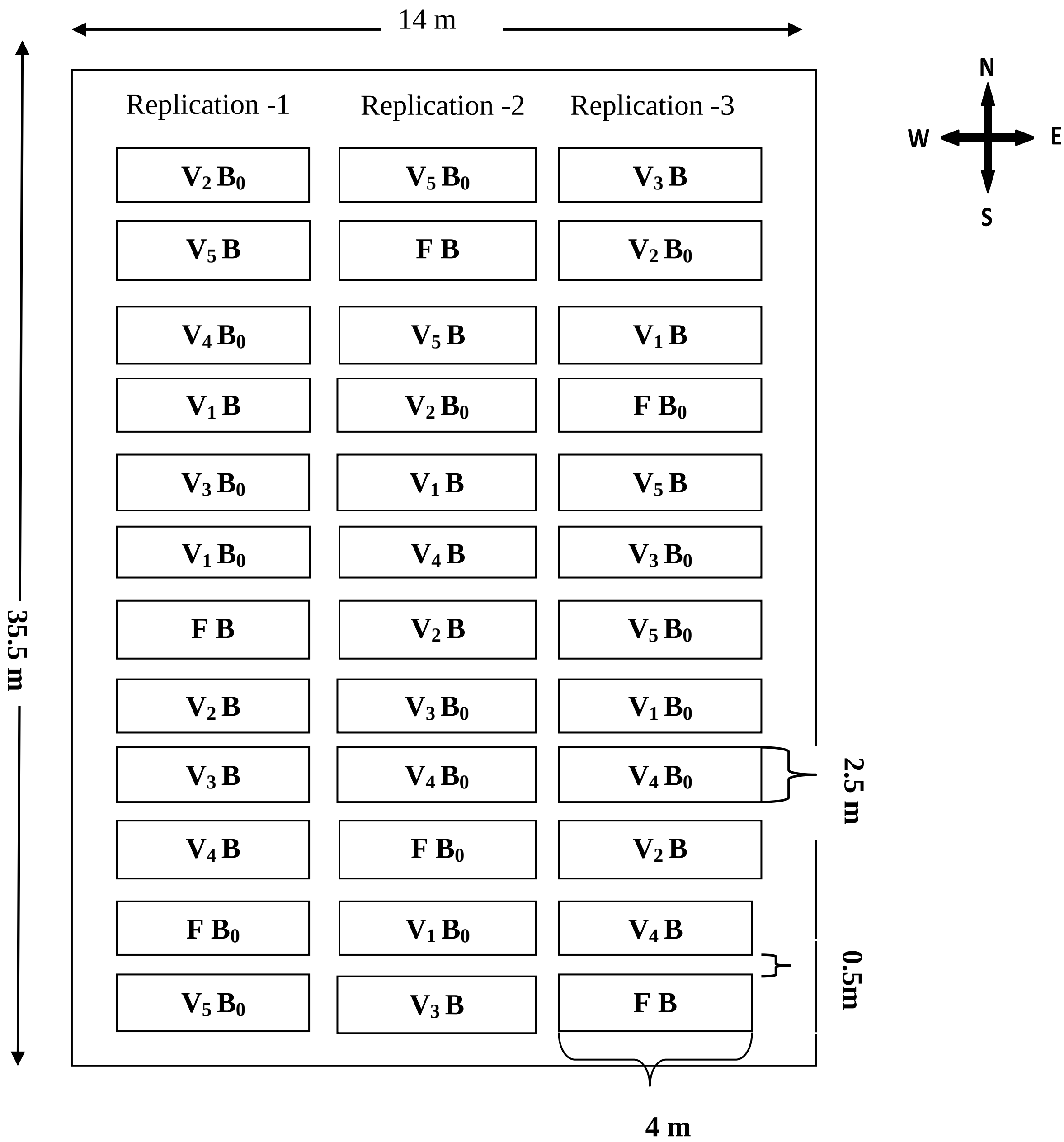


V_1= Tori 7
V_2= BARI Sarisha-8
V_3= BARI Sarisha-11
V_4= BARI Sarisha-13
V_5= BARI Sarisha-15

Figure 1: Lay out of the experimental plot (*Brassica*)

3.6.2 Layout of main experiment

The layout of the wheat field remained undisturbed as *Brassica* field. The experiment was laid out in randomized complete block design with three replications. The experimental unit was divided into three blocks each of which representing a replication. Each block was divided into twelve plots where were two plots were kept fallow and 5 varieties of *Brassica* sown in 5×2= 10 plots. Of the two plots of cultivating same variety of *Brassica* one plot was incorporated with that of 30 days old *Brassica* biomass of the same variety and another was kept undisturbed after harvesting *Brassica* at 30 DAS. One of the two fallow plots was incorporated with the biomass mixture of 5 varieties. So, the total number of plots in the entire experimental plot was 36. BARI gom - 25 was sown in all the plots. Size of each unit plot was 2.5 m × 4 m = 10 m^2. The distance maintained between plot-plot and between blocks was 0.5m (Figure 2).



V_1 = Tori 7

V_2= BARI Sarisha 8

V_3= BARI Sarisha 11

V_4= BARI Sarisha 13

V_5= BARI Sarisha 15

B = Brassica biomass added to the soil

B_0= No biomass added to the soil

F=Fallow for *Brassica*

Figure 2. Layout of the experimental plot of wheat containing combination of treatments in individual plot

3.7 Details of the field operations

The particulars of the cultural operations carried out during the experimentation are 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 first field layout for sowing *Brassica* species was made on 29th October 2011, according to design, immediately after final land preparation. The field was divided to in three blocks and each of the blocks was divided into 12 plots. The *Brassica* variety Tori 7, BARI Sarisha 8, BARI Sarisha 11, BARI Sarisha 13, BARI Sarisha 15 were sown in the field on 30th October. Each of 5 varieties of *Brassica* was sown in two plots of the each block and two plots of each block remains fallow. Harvesting of all 5 *Brassica* varieties was done at their 30 DAS (29.11.11). Out of the two plots of individual variety, biomass of one plot was incorporated with soil of the same plot and *Brassica* biomass of another plot was maintained for other plot without any biomass incorporation in it. One fallow plot of each block was incorporated with biomass mixture of 5 varieties and other plot was maintained fallow. *Brassica* biomass was used in green form @ 1 kg m^{-2} .Same procedure was followed for the five *Brassica* varieties consecutively in three blocks. The final land preparation for wheat 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 a 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), murate of potash (MoP), gypsum, zinc sulphate and boric acid at the rate of 250-170-85-150-5 and 10 kg ha^{-1} respectively. Only a half of individual fertilizer doses for *Brassica* was applied at final land preparation as *Brassica* was uprooted after one month.

The main experimental field was fertilized with urea, triple super phosphate (TSP), muriate of potash (MoP) and gypsum at the rate of 220, 180, 50 and 120 kg ha^{-1} respectively. The whole amount of triple super phosphate (TSP), muriate of potash (MoP), gypsum and one third of urea were mixed with soil at the time of final land preparation. The remaining urea was applied in two installments, at crown root initiation stage (20 days after sowing) and prior to spike initiation stage (55 days after sowing) as top dressing.

3.7.3 Collection and sowing of seeds

The *Brassica* seeds (Tori-7, BARI Sarisha-8, BARI Sarisha-11, BARI Sarisha-13, 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 wheat seeds (cv. BARI gom-25) were collected from Wheat 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 20 cm line to line distance. After sowing, seeds were covered with soil and slightly pressed by hand.

3.7.4 Irrigation

The experimental plot was irrigated three times. The first, second and third irrigations were applied at crown root initiation stage, heading stage and grain filling stage respectively (20, 55, 70 days after sowing). Proper drainage system was maintained to remove the excess amount of water from the plot.

3.7.5 Pest management

In the whole period of experiment, no infestation of diseases and pest were found. Zinc phosphide was applied several times to control rat. Special attentions were undertaken to protect the crop from the attack of parrots, pigeons and other birds.

3.7.6 Harvesting and sampling

The wheat crop was harvested at maturity on March 21, 2012. Samples were collected from different places of each plot leaving middle six rows in the centre undisturbed and two border rows as itself. The selected sample plants were then tagged and carefully carried out to the Agronomy field laboratory in order to collect data. Sampling of central 4.5 m^2 area was done plot-wise and bundled the plants with separate tags. The crop bundles were sun dried on the threshing floor. 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. Weed population
2. Dry weight of weed biomass

3.8.2 Data regarding different crop characters and yield of wheat

1. Plant height at different growth duration
2. Dry weight of plants at different growth duration
3. Number of tillers m^{-1} (linear)
4. Number of leaves $plant^{-1}$
5. Spike length
6. Number of filled grains $spike^{-1}$
7. 1000 grain weight
8. Grain yield

9. Straw yield
10. Husk yield
11. Biological yield
12. Harvest index

3.8.1.1 Weed population

From the 0.5 m^2 area of each plot, the total weeds were uprooted and counted at 30, 60 and 90 DAS respectively.

3.8.1.2 Dry weight of weed biomass

The collected weeds of each plot were 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.

3.8.2 Crop characters, yield contributing characters and yield of wheat

3.8.2.1 Plant height

The height of wheat plant was recorded during harvest at 25, 50, and 75 days after sowing (DAS). 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

Plants were uprooted from 0.25 linear meters area of inner rows of the plot at 30, 60, 90 DAS and at harvesting respectively. After drying at oven (80ºC) the samples were then transferred into desiccators and allowed to cool down to the room temperature. Then final weights of the samples were taken and values were converted to g m^{-2}.

3.8.2.3 Number of tillers linearmeter^{-1}

The total number of spikelet bearing tillers and non spikelet bearing tillers in linearmeter^{-1} were counted. The total number of non-spikelet bearing tillers linearmeter^{-1} was also counted.

3.8.2.4 Number of leaves plant^{-1}

Number of leaves of individual plant was recorded from the selected plants at 25, 50, 75 days after sowing (DAS) from the same pre-selected plants. To measure plant leaf number ten plants were randomly selected from each plot tagged, counted and averaged.

3.8.2.5 Spike length

The length of spike was measured by using a meter scale. The measurement was taken from base to tip of the spike. Average length of spike was taken from ten randomly selected spikes. The data was recorded at harvest time and the mean data was expressed in centimeter (cm).

3.8.2.6 Number of filled grains spike^{-1}

The total number of filled grains spike^{-1} was counted. Average data were recorded randomly from ten spike bearing plants in each plot during the time of harvest.

3.8.2.7 1000 grain weight

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

3.8.2.8 Grain yield

Inner 4.5 m^2 area of each plot was 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

The straw weight was determined after threshing (4.5 m^2 area) and drying and finally converted them into t ha^{-1}.

3.8.2.10 Husk yield

The husk weight was also determined after threshing (4.5 m^2 area) and drying and finally converted them into t ha^{-1}.

3.8.2.11 Biological yield

Biological yield was determined as below;

Biological yield = Grain yield + straw yield + husk yield

3.8.2.12 Harvest index

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

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

3.9 Statistical analysis

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 present experiment was conducted to study the 'Efficacy of *Brassica* varieties to control weeds in wheat'. The analysis of variance data on weed, different crop and yield contributing characters as well as yield of wheat as influenced by different varieties of *Brassica* biomass has been presented in this chapter. The results have been presented and discussed under the following headings.

2.1 Effect on weed population

Weed population in wheat field varied significantly for different *Brassica* varieties and incorporation of their biomass (Appendix I -II and Table 1).

The highest weed populations (230.80 m^{-2}) was recorded in T_1 treatment (no *Brassica* + no biomass) and that of the lowest (100.40 m^{-2}) in T_6 treatment {*Brassica* (BARI Sarisha-8) with biomass of same variety} which was statistically similar with T_4, T_7, T_8, T_{10} and T_{12} treatments at 30 DAS.

At 60 DAS, T_1 treatment (no *Brassica* + no biomass) resulted the highest weed population (300.70 m^{-2}). The lowest weed population (181.30 m^{-2}) obtained from T_6 treatment (*Brassica* (BARI Sarisha-8) with biomass of same variety) which was statistically similar with the $T_{3,}$ T_4, T_5, T_7, T_8, T_9, T_{10}, T_{11} and T_{12} treatments.

As treatments T_4, T_6, T_8, T_{10} and T_{12} showed statistically similar weed population and all of are designated with different varieties so it may be noted that weed populations were varied due to inclusions of biomass irrespective of variety. Incorporation of *Brassica* biomass reduced 35% and 21% weed population in wheat field compared to that of T_1 (no *Brassica* crop and no *Brassica* biomass).

Table 1. Effect of *Brassica* variety and their biomass on weed population of wheat.

Treatments	Weed population (No m^{-2})	
	30 DAS	**60 DAS**
T_1	230.80 a	300.70 a
T_2	150.70 bc	237.00 b
T_3	147.90 bc	203.30 bc
T_4	113.00 cd	192.00 c
T_5	160.00 b	224.70 bc
T_6	100.40 d	181.30 c
T_7	136.30 bcd	204.00 bc
T_8	111.30 cd	183.00 c
T_9	168.30 b	220.70 bc
T_{10}	127.30 bcd	199.30 bc
T_{11}	161.70 b	209.30 bc
T_{12}	117.30 cd	185.00 c
SE	12.92	12.92
CV (%)	9.87	10.57

T_1 : No *Brassica* + no biomass (Control),
T_2 : No *Brassica* + biomass of 5 varieties
T_3 : *Brassica* (Tori 7) without biomass,
T_4 : *Brassica* (Tori 7) with biomass of same variety,
T_5 : *Brassica* (BARI Sarisha - 8) without biomass,
T_6 : *Brassica* (BARI Sarisha - 8) with biomass of the same variety ,
T_7 : *Brassica* (BARI Sarisha - 11) without biomass,
T_8 : *Brassica* (BARI Sarisha - 11) with biomass of the same variety,
T_9 : *Brassica* (BARI Sarisha - 13) without biomass ,
T_{10} : *Brassica* (BARI Sarisha - 13) with biomass of the same variety,
T_{11} : *Brassica* (BARI Sarisha - 15) without biomass,
T_{12} : *Brassica* (BARI Sarisha - 15) with biomass of the same variety.

Similar results found by Rahman *et al.* (2012b) who noted that weed population and weed dry weight showed 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.

2.2 Effect on dry weight of weed

Statistically significant variation observed in dry weight of weed in wheat field for different *Brassica* varieties and their biomass (Appendix III-IV and Table 2).

At 30 DAS, the highest dry weight of weed (29.14 g m^{-2}) in wheat field was observed in T_1 treatment (no *Brassica* + no biomass). The lowest dry weight of weed (8.33 g m^{-2}) in wheat field was observed in T_6 treatment {*Brassica* (BARI Sarisha-8) with biomass of same variety} which was statistically similar with T_4, T_8, T_{10} and T_{12} treatments.

The variation in dry weight of weed in wheat field was significant for *Brassica* varieties and their biomass at 60 DAS. The highest weed dry weight (57.51 g m^{-2}) was recorded from T_1 treatment (no *Brassica* + no biomass) and the lowest weed dry weight (22.98 g m^{-2}) recorded from T_{12} treatment {*Brassica* (BARI Sarisha - 15) with biomass of same variety} which was statistically similar with T_4, T_6, T_8, T_{10} treatments. At 60 DAS the treatments, which were previously cultivated with *Brassica* and also with biomass applied showed comparatively lower weed dry weight than others.

Table 2. Effect of *Brassica* variety and their biomass on weed dry weight of wheat

Treatments	Dry weight of weed (g m^{-2})	
	30 DAS	**60 DAS**
T_1	29.14 a	57.51 a
T_2	19.18 b	39.32 b
T_3	17.79 b	42.38 b
T_4	9.43 d	29.45 cd
T_5	19.28 b	40.29 b
T_6	8.33 d	24.93 d
T_7	15.74 bc	38.69 b
T_8	10.68 cd	27.99 cd
T_9	18.87 b	34.74 bc
T_{10}	11.10 cd	28.61 cd
T_{11}	17.82 b	37.89 b
T_{12}	11.21 cd	22.98 d
SE	1.863	2.630
CV (%)	20.53	12.87

T_1 : No *Brassica* + no biomass (Control),
T_2 : No *Brassica* + biomass of 5 varieties
T_3 : *Brassica* (Tori 7) without biomass,
T_4 : *Brassica* (Tori 7) with biomass of same variety,
T_5 : *Brassica* (BARI Sarisha - 8) without biomass,
T_6 : *Brassica* (BARI Sarisha - 8) with biomass of the same variety ,
T_7 : *Brassica* (BARI Sarisha - 11) without biomass,
T_8 : *Brassica* (BARI Sarisha - 11) with biomass of the same variety,
T_9 : *Brassica* (BARI Sarisha - 13) without biomass ,
T_{10} : *Brassica* (BARI Sarisha - 13) with biomass of the same variety,
T_{11} : *Brassica* (BARI Sarisha - 15) without biomass,
T_{12} : *Brassica* (BARI Sarisha - 15) with biomass of the same variety.

The treatments along with *Brassica* and their biomass (T_4, T_6, T_8, T_{10} and T_{12}) showed comparatively lower weed dry weight than the treatment with only *Brassica* where no biomass applied.

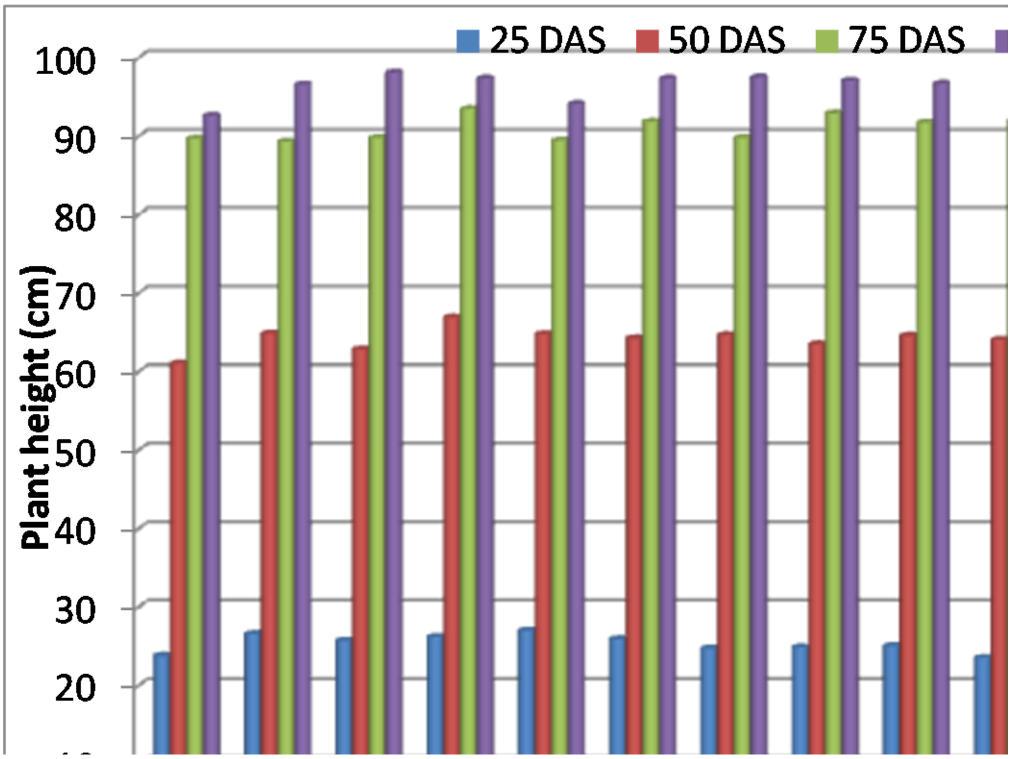
As treatments T_4, T_6, T_8, T_{10} and T_{12} represents different variety and showed statistically similar weed dry weight so it may be noted that weed dry weight was not varied for varietal variation but for biomass incorporation.

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%. These results disagree with Biswas *et al*. (2008) who reported that weed dry weight in wheat field varied along with *Brassica* varieties.

2.3 Effect on plant height

Plant height of wheat increased with the advancement of plant age. Plant height of wheat varied significantly for *Brassica* varieties and their biomass at 50 DAS. Statistically no significant variation observed in plant for *Brassica* varieties and their biomass at 25 DAS, 75 DAS and at harvest (Appendix V-VIII and Figure 3).

At 25 DAS, maximum plant height (27.03 cm) was found in T_5 treatment {*Brassica* (BARI Sarisha 8) without biomass} and the minimum plant height (23.55 cm) found in T_{10} treatment {*Brassica* (BARI Sarisha - 13) with biomass of same variety}.



T_1 : No *Brassica* + no biomass (Control),
T_2 : No *Brassica* + biomass of 5 varieties
T_3 : *Brassica* (Tori 7) without biomass,
T_4 : *Brassica* (Tori 7) with biomass of same variety,
T_5 : *Brassica* (BARI Sarisha - 8) without biomass,
T_6 : *Brassica* (BARI Sarisha - 8) with biomass of the same variety ,
T_7 : *Brassica* (BARI Sarisha - 11) without biomass,
T_8 : *Brassica* (BARI Sarisha - 11) with biomass of the same variety,
T_9 : *Brassica* (BARI Sarisha - 13) without biomass ,
T_{10} : *Brassica* (BARI Sarisha - 13) with biomass of the same variety,
T_{11} : *Brassica* (BARI Sarisha - 15) without biomass,
T_{12} : *Brassica* (BARI Sarisha - 15) with biomass of the same variety.

Figure 3. Effect of *Brassica* variety and their biomass on plant height of wheat [SE= 1.688]

At 50 DAS, the T_4 treatment {*Brassica* (Tori 7) with biomass of same variety} resulted with the highest plant height (66.93 cm), which was statistically similar with T_2, T_3, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11} and T_{12}. The lowest plant height (61.07 cm) was obtained from the T_1 treatment (no *Brassica* + no biomass).

At 75 DAS, no significant difference was observed on plant height, though maximum (93.47 cm) plant height was recorded from T_4 treatment {*Brassica*

(Tori 7) with biomass of same variety} and minimum (85.07 cm) from T_{11} treatment {*Brassica* (BARI Sarisha - 15) without biomass}.

At harvest, the maximum plant height (98.13cm) was recorded from T_3 treatment {*Brassica* (Tori 7) without biomass} and the minimum plant height (92.63 cm) was recorded from T_1 treatment (no *Brassica*+ no biomass).

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 the growth of wheat. Similar results also obtained by 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.*

2.4 Effect on leaf number $plant^{-1}$

Number of leaf $plant^{-1}$ of wheat increased with the advancement of plant age. At 25 DAS, it varied significantly in plots treated with *Brassica* varieties and their biomass. No significant variation observed on the same for *Brassica* varieties and their biomass, at 50 and 75 DAS (Appendix IX-XII and Table 3).

At 25 DAS, T_{12} treatment {*Brassica* (BARI Sarisha-15) with biomass of same variety} resulted the highest number of leaves $plant^{-1}$ (9.50) which was statistically similar with T_2, T_3, and T_4 treatments. At same age of plant the lowest number of leaves $plant^{-1}$ of wheat (6.83) was observed in T_1 treatment (no *Brassica* + no biomass) which was statistically similar with T_5, T_6, T_7, T_8, T_9, T_{10} and T_{11} treatments.

Table 3. Effect of *Brassica* variety and their biomass on number of leaf plant^{-1} of wheat

Treatments	Number of leaves plant^{-1} (No.)		
	25 DAS	**50DAS**	**75 DAS**
T_1	6.83 d	20.00	20.83
T_2	9.00 ab	23.50	24.00
T_3	8.67 abc	23.00	23.67
T_4	8.33 abc	21.17	21.67
T_5	7.33 cd	22.00	23.00
T_6	6.83 d	21.83	22.33
T_7	8.00 bcd	21.33	21.67
T_8	8.00 bcd	23.33	23.83
T_9	8.00 bcd	23.00	24.00
T_{10}	8.00 bcd	23.33	23.50
T_{11}	8.00 bcd	21.33	22.50
T_{12}	9.50 a	21.83	22.83
SE	0.4135	NS	NS
CV (%)	8.91	8.13	7.83

T_1 : No *Brassica* + no biomass (Control),
T_2 : No *Brassica* + biomass of 5 varieties
T_3 : *Brassica* (Tori 7) without biomass,
T_4 : *Brassica* (Tori 7) with biomass of same variety,
T_5 : *Brassica* (BARI Sarisha - 8) without biomass,
T_6 : *Brassica* (BARI Sarisha - 8) with biomass of the same variety ,
T_7 : *Brassica* (BARI Sarisha - 11) without biomass,
T_8 : *Brassica* (BARI Sarisha - 11) with biomass of the same variety,
T_9 : *Brassica* (BARI Sarisha - 13) without biomass ,
T_{10} : *Brassica* (BARI Sarisha - 13) with biomass of the same variety,
T_{11} : *Brassica* (BARI Sarisha - 15) without biomass,
T_{12} : *Brassica* (BARI Sarisha - 15) with biomass of the same variety.

At 50 DAS, statistically no significant variation observed on leaf number plant^{-1} of wheat though T_2 treatment (no *Brassica* + biomass of 5 varieties) showed the maximum number of leaves plant^{-1} (23.50) and T_1 treatment showed the minimum number of leaves plant^{-1} of wheat (20.00).

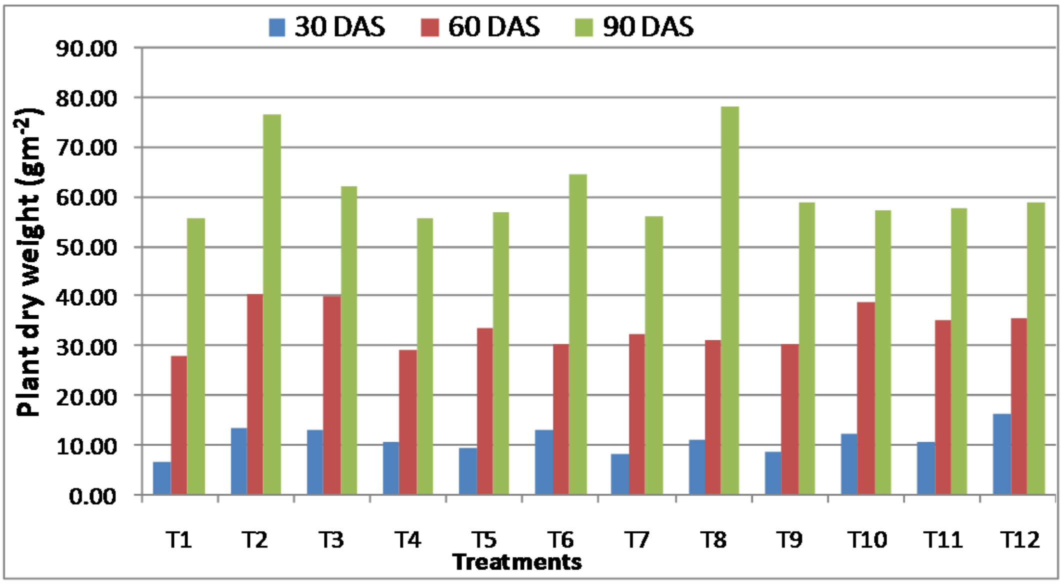
At 75 DAS, T_2 treatment showed the highest number of leaves plant^{-1} (24.00) and T_1 treatment showed the lowest number of leaves plant^{-1} (20.83) of wheat.

2.5 Effect on plant dry weight

The plant dry weight of wheat was increased with the advancement of plant age. The significant variation observed at 30 DAS but there was no significant variation found in plant dry weight at 60 DAS and 90 DAS for *Brassica* varieties and their biomass (Appendix XII-XIV and Figure 4).

At 30 DAS, the highest plant dry weight (16.03 g m^{-2}) was obtained from T_{12} treatments {*Brassica* (BARI Sarisha 15) with biomass of same variety} which was statistically similar with T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11} treatment and the lowest plant dry weight (6.44 g m^{-2}) was obtained from T_1 treatment (no *Brassica* + no biomass).

At 60 DAS, the maximum plant dry weight of wheat (40.08 g m^{-2}) was recorded from T_2 treatment (no *Brassica* + biomass of 5 varieties) and the minimum plant dry weight (27.85 g m^{-2}) of wheat was recorded from T_1 treatment (no *Brassica* + no biomass).



T_1 : No *Brassica* + no biomass (Control),
T_2 : No *Brassica* + biomass of 5 varieties
T_3 : *Brassica* (Tori 7) without biomass,
T_4 : *Brassica* (Tori 7) with biomass of same variety,
T_5 : *Brassica* (BARI Sarisha - 8) without biomass,
T_6 : *Brassica* (BARI Sarisha - 8) with biomass of the same variety ,
T_7 : *Brassica* (BARI Sarisha - 11) without biomass,
T_8 : *Brassica* (BARI Sarisha - 11) with biomass of the same variety,
T_9 : *Brassica* (BARI Sarisha - 13) without biomass ,
T_{10} : *Brassica* (BARI Sarisha - 13) with biomass of the same variety,
T_{11} : *Brassica* (BARI Sarisha - 15) without biomass,
T_{12} : *Brassica* (BARI Sarisha - 15) with biomass of the same variety.

Figure 4. Effect of *Brassica* variety and biomass on plant dry weight of wheat [SE= 2.641]

At 90 DAS, the maximum plant dry weight of wheat (78.07 g m^{-2}) was observed in T_8 treatment {*Brassica* (BARI Sarisha - 11) with biomass of same variety} and the minimum plant dry weight of wheat (55.46 g m^{-2}) was observed in T_1 treatments (no *Brassica* + no biomass).

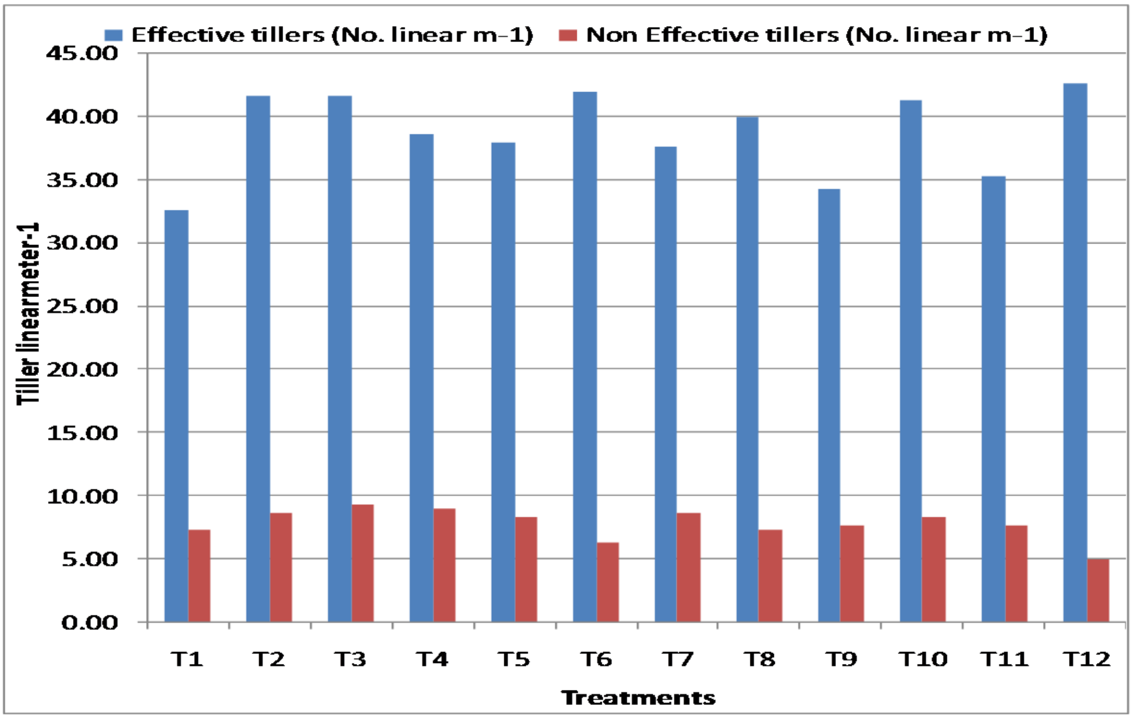
These results agreed with Rahman *et al.* (2012b) who noted that land with *Brassica* and application of 35 days old *Brassica* biomass @ 0.5 -1.0 kg m^{-2} increased growth of wheat. This results also in agreement with Khan *et al.* (2005) who showed that the allelopathic potential of aqueous extracts 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.*

2.6 Effect on tillers

The number of effective tillers per linear meter and non effective tillers per linear meter varied significantly for the effect of different *Brassica* varieties and their biomass (Appendix XV-XVI and Figure 5).

The highest number of effective tiller linearmeter^{-1} (42.67) was found in T_{12} treatment {*Brassica* (BARI Sarisha-15) with biomass of same variety} which was statistically similar with T_2, T_3, T_4, T_5, T_6. T_7, T_8. $T_{9,}$ T_{10} and T_{11} treatments. The lowest number of effective tiller per linear meter (32.67 m^{-1}) was recorded in T_1 treatment (no *Brassica* + no biomass).

The highest number of non effective tillers linearmeter^{-1} (9.33) was recorded from T_3 treatment {*Brassica* (Tori 7) without biomass } which was statistically similar with T_1, T_2, T_4, T_5, T_7, T_8, T_9, T_{10} and T_{11} treatments. The lowest number of effective tillers linearmeter^{-1} (5.00) was recorded from T_{12} treatment which was statistically similar with T_1, T_6 and T_8 treatments.



T_1 : No *Brassica* + no biomass (Control),
T_2 : No *Brassica* + biomass of 5 varieties
T_3 : *Brassica* (Tori 7) without biomass,
T_4 : *Brassica* (Tori 7) with biomass of same variety,
T_5 : *Brassica* (BARI Sarisha - 8) without biomass,
T_6 : *Brassica* (BARI Sarisha - 8) with biomass of the same variety ,
T_7 : *Brassica* (BARI Sarisha - 11) without biomass,
T_8 : *Brassica* (BARI Sarisha - 11) with biomass of the same variety,
T_9 : *Brassica* (BARI Sarisha - 13) without biomass ,
T_{10} : *Brassica* (BARI Sarisha - 13) with biomass of the same variety,
T_{11} : *Brassica* (BARI Sarisha - 15) without biomass,
T_{12} : *Brassica* (BARI Sarisha - 15) with biomass of the same variety.

Figure 5. Effect of *Brassica* variety and their biomass on effective and non - effective tillers of wheat [SE = ± 2.628, 0.775 for effective and non effective tillers respectively]

2.7 Effect on spike length

There was no significant variation observed on spike length for the effect of different *Brassica* varieties and incorporation of their biomass (Appendix XVII and Figure 6).

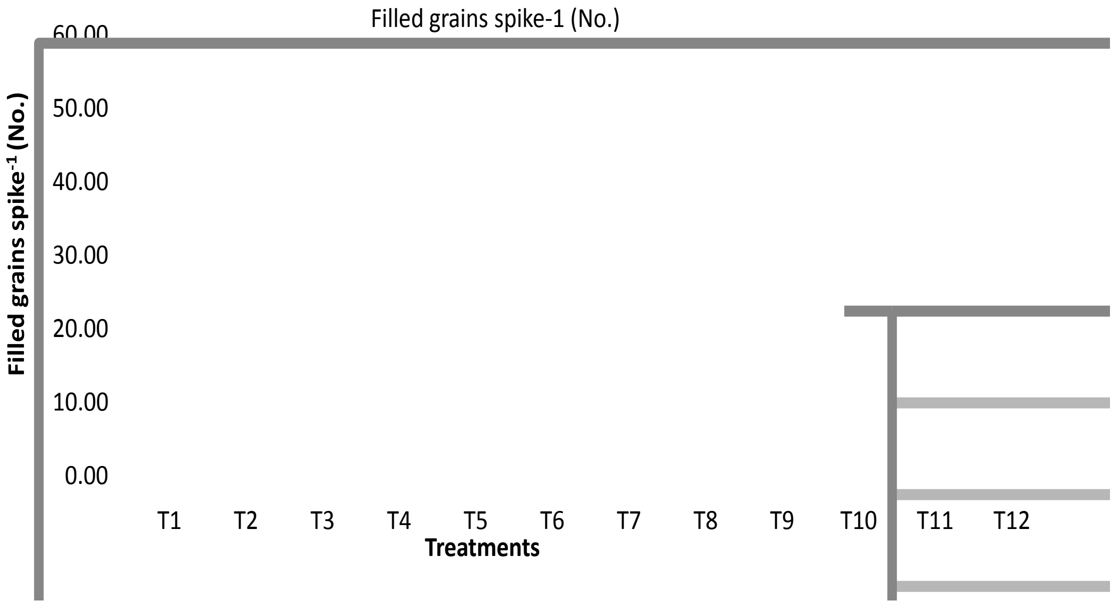
T_1 : No *Brassica* + no biomass (Control),
T_2 : No *Brassica* + biomass of 5 varieties
T_3 : *Brassica* (Tori 7) without biomass,
T_4 : *Brassica* (Tori 7) with biomass of same variety,
T_5 : *Brassica* (BARI Sarisha - 8) without biomass,
T_6 : *Brassica* (BARI Sarisha - 8) with biomass of the same variety ,
T_7 : *Brassica* (BARI Sarisha - 11) without biomass,
T_8 : *Brassica* (BARI Sarisha - 11) with biomass of the same variety,
T_9 : *Brassica* (BARI Sarisha - 13) without biomass ,
T_{10} : *Brassica* (BARI Sarisha - 13) with biomass of the same variety,
T_{11} : *Brassica* (BARI Sarisha - 15) without biomass,
T_{12} : *Brassica* (BARI Sarisha - 15) with biomass of the same variety.

Figure 6. Effect of *Brassica* variety and their biomass on spike length of Wheat [SE = ± 0.476]

The T_4 treatment {*Brassica* (Tori 7) with biomass of same variety} resulted the maximum spike length (15.95 cm) and the minimum spike length (14.99 cm) observed in T_1 treatment (no *Brassica* + no biomass) though statistically no variation observed among the treatments.

2.8 Effect on filled grain spike^{-1}

Brassica varieties and their biomass showed significant variation on filled grains spike^{-1} of wheat (Appendix XVIII and Figure 7).



T_1 : No *Brassica* + no biomass (Control),
T_2 : No *Brassica* + biomass of 5 varieties
T_3 : *Brassica* (Tori 7) without biomass,
T_4 : *Brassica* (Tori 7) with biomass of same variety,
T_5 : *Brassica* (BARI Sarisha - 8) without biomass,
T_6 : *Brassica* (BARI Sarisha - 8) with biomass of the same variety ,
T_7 : *Brassica* (BARI Sarisha - 11) without biomass,
T_8 : *Brassica* (BARI Sarisha - 11) with biomass of the same variety,
T_9 : *Brassica* (BARI Sarisha - 13) without biomass ,
T_{10} : *Brassica* (BARI Sarisha - 13) with biomass of the same variety,
T_{11} : *Brassica* (BARI Sarisha - 15) without biomass,
T_{12} : *Brassica* (BARI Sarisha - 15) with biomass of the same variety.

Figure 7. Effect of *Brassica* variety and their biomass on filled grain spike^{-1} of wheat [SE = ± 2.172]

The highest number of filled grains spike^{-1} (47.93) was recorded from T_2 treatments (no *Brassica*+ biomass of 5 varieties) which was statistically similar with T_3, T_4, T_5, T_6, T_7, T_8, T_{10}, T_{11} and T_{12} treatments.

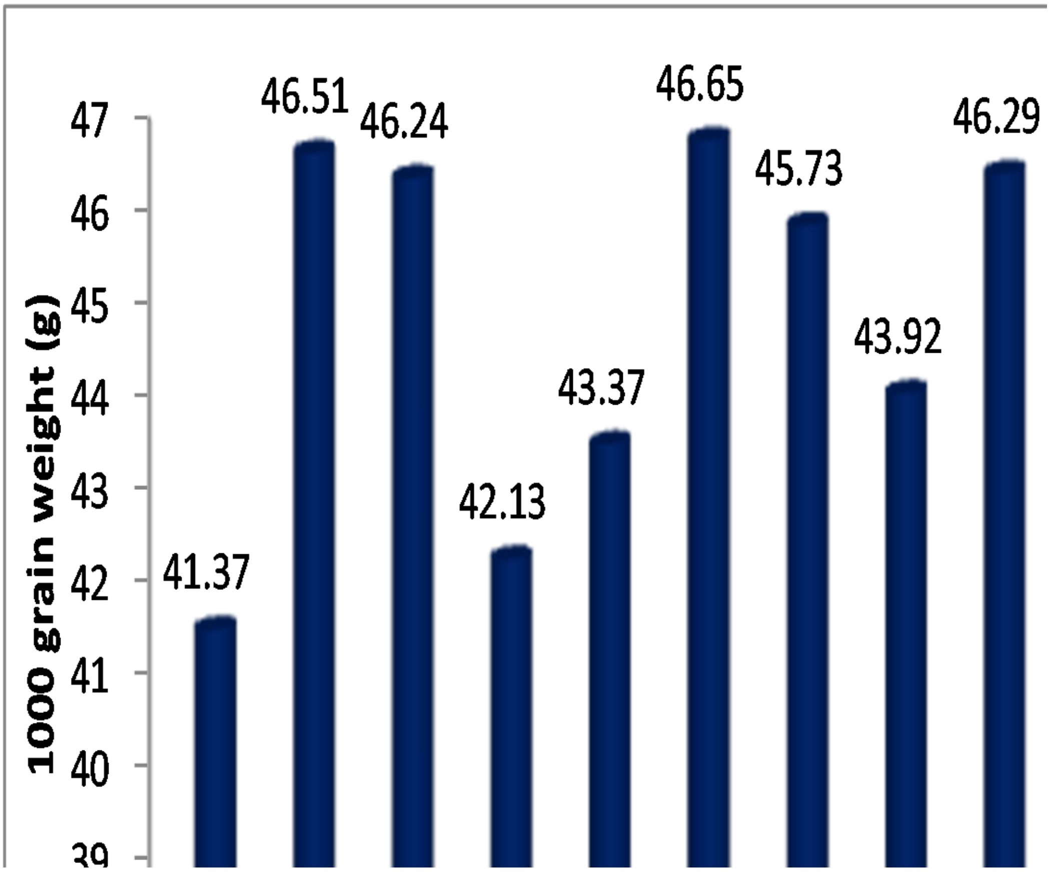
The lowest number of filled grains spike^{-1} (38.07) was obtained from T_1 treatment (no *Brassica* + no biomass) which was statistically similar with T_5, T_7, T_8, T_9 and T_{11} treatments.

2.9 Effect on thousand grain weight

There was no significant variation observed on thousand grain weights for the effect of *Brassica* and their biomass (Appendix XIX and Figure 8).

Though there was no significant variation observed on thousand grain weight, the maximum thousand grain weight (46.86 g) obtained from T_{12} treatment {*Brassica* (BARI Sarisha 15) with biomass of same variety} and the minimum value (41.37 g) recorded from T_1 treatment (no *Brassica* + no biomass).

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



T_1 : No *Brassica* + no biomass (Control),
T_2 : No *Brassica* + biomass of 5 varieties
T_3 : *Brassica* (Tori 7) without biomass,
T_4 : *Brassica* (Tori 7) with biomass of same variety,
T_5 : *Brassica* (BARI Sarisha - 8) without biomass,
T_6 : *Brassica* (BARI Sarisha - 8) with biomass of the same variety ,
T_7 : *Brassica* (BARI Sarisha - 11) without biomass,
T_8 : *Brassica* (BARI Sarisha - 11) with biomass of the same variety,
T_9 : *Brassica* (BARI Sarisha - 13) without biomass ,
T_{10} : *Brassica* (BARI Sarisha - 13) with biomass of the same variety,
T_{11} : *Brassica* (BARI Sarisha - 15) without biomass,
T_{12} : *Brassica* (BARI Sarisha - 15) with biomass of the same variety.

Figure 8. Effect of *Brassica* variety and their biomass on thousand grain weight of wheat [SE = ± 1.777]

2.10 Effect on grain yield

There was significant variation observed on grain yield of wheat for effect of different *Brassica* variety and their biomass (Appendix XX and Table 4).

The highest grain yield (1.75 t ha^{-1}) was found in T_{12} treatment {*Brassica* (BARI Sarisha - 15) with biomass of same variety} which was statistically similar with T_3, T_5, T_6, T_7, T_8 and T_{10} treatments. The lowest grain yield (1.36 t ha^{-1}) was found from T_1 treatment (no *Brassica*+ no biomass) which was statistically similar with T_2, T_3, T_4, T_5, $T_{9,}$ T_{10} and T_{11} treatment. BARI Sarisha -8, BARI Sarisha -11 and BARI Sarisha -15 with *Brassica* biomass of same variety application showed the highest grain yield of wheat. The T_1 treatment (no *Brassica* + no biomass) gave 19%, 20% and 21% lower wheat grain yield compared to T_8 {*Brassica* (BARI Sarisha - 11) with biomass of the same variety}, T_6 {*Brassica* (BARI Sarisha - 8) with biomass of the same variety} and T_{12} {*Brassica* (BARI Sarisha - 15) with biomass of the same variety} respectively.

These results agreed with Rahman *et al.* (2012a) who stated 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. These results also agreed with 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% and enhanced yield of wheat, maize, cotton and rice by 15 to 25%. Similar results also obtained by Boydston and Hang (1995) who 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.

2.11 Effect on straw yield

Statistically significant variation observed on straw yield of wheat for the variation of *Brassica* variety and their biomass (Appendix XXI and Table 4).

The highest straw yield (2.20 t ha^{-1}) was obtained from T_8 treatment {*Brassica* (BARI Sarisha - 8) with biomass of same variety} which was statistically similar with T_2, T_5, T_6, T_7, T_{10} and T_{12} treatments.

T_{11} treatment {*Brassica* (BARI Sarisha - 15) without biomass} resulted lowest straw yield (1.63 t ha^{-1}) which was statistically similar with T_1, T_2, T_3, T_4, T_5, T_7, T_9, T_{10} T_{11} and T_{12} treatments.

2.12 Effect on husk yield:

Different *Brassica* varieties and their biomass showed significant variation on husk yield of wheat (Appendix XXII and Table 4).

The highest husk yield (0.87 t ha^{-1}) was observed in T_7 treatment {*Brassica* (BARI Sarisha-11) without biomass} which was statistically similar with T_{11} treatment {*Brassica* (BARI Sarisha-15) without biomass}.

The lowest husk yield (0.47 t ha^{-1}) was recorded from T_5 treatment {*Brassica* (BARI Sarisha-8) without biomass} which was statistically similar with T_1, T_2, T_3, T_4, T_6, T_8, T_9, T_{10} and T_{12} treatments.

Table4. Effect of *Brassica* variety and their biomass on yield of wheat

Treatments	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Husk yield ($t\ ha^{-1}$)	Biological Yield ($t\ ha^{-1}$)
T_1	1.36 c	1.65 bc	0.55c	3.58 d
T_2	1.38 c	1.97 abc	0.62 bc	3.97 abcd
T_3	1.58 abc	1.75 bc	0.50 c	3.83 bcd
T_4	1.38 c	1.70 bc	0.57 c	3.65 d
T_5	1.55 abc	1.97 abc	0.47 c	3.98 abcd
T_6	1.73 a	2.07 ab	0.56 c	4.35 abc
T_7	1.68 ab	1.90 abc	0.87 a	4.45 ab
T_8	1.73 a	2.20 a	0.59 bc	4.51 a
T_9	1.40 bc	1.65 bc	0.55 c	3.60 d
T_{10}	1.62 abc	1.80 abc	0.57 c	3.98 abcd
T_{11}	1.37 c	1.63 c	0.77 ab	3.76 cd
T_{12}	1.75 a	1.83 abc	0.48 c	4.07 abcd
SE	0.0876	0.127	0.061	0.192
CV (%)	9.78%	11.89%	17.53%	8.39%

T_1 : No *Brassica* + no biomass (Control),
T_2 : No *Brassica* + biomass of 5 varieties
T_3 : *Brassica* (Tori 7) without biomass,
T_4 : *Brassica* (Tori 7) with biomass of same variety,
T_5 : *Brassica* (BARI Sarisha - 8) without biomass,
T_6 : *Brassica* (BARI Sarisha - 8) with biomass of the same variety ,
T_7 : *Brassica* (BARI Sarisha - 11) without biomass,
T_8 : *Brassica* (BARI Sarisha - 11) with biomass of the same variety,
T_9 : *Brassica* (BARI Sarisha - 13) without biomass ,
T_{10} : *Brassica* (BARI Sarisha - 13) with biomass of the same variety,
T_{11} : *Brassica* (BARI Sarisha - 15) without biomass,
T_{12} : *Brassica* (BARI Sarisha - 15) with biomass of the same variety.

2.13 Effect on biological yield

Different *Brassica* varieties and their biomass significantly influenced the biological yield of wheat (Appendix XXIII and Table 4).

The T_8 treatment {*Brassica* (BARI Sarisha-11) with biomass of the same variety} resulted the highest biological yield (4.51 t ha^{-1}) which was statistically similar with T_2, T_5, T_6, T_7, T_{10} and T_{12} treatments. The lowest biological yield (3.58 t ha^{-1}) was recorded from T_1 treatment (no *Brassica* + no biomass) which was statistically similar with T_2, T_3, T_4, T_5, T_9, T_{10}, T_{11} and T_{12} treatments.

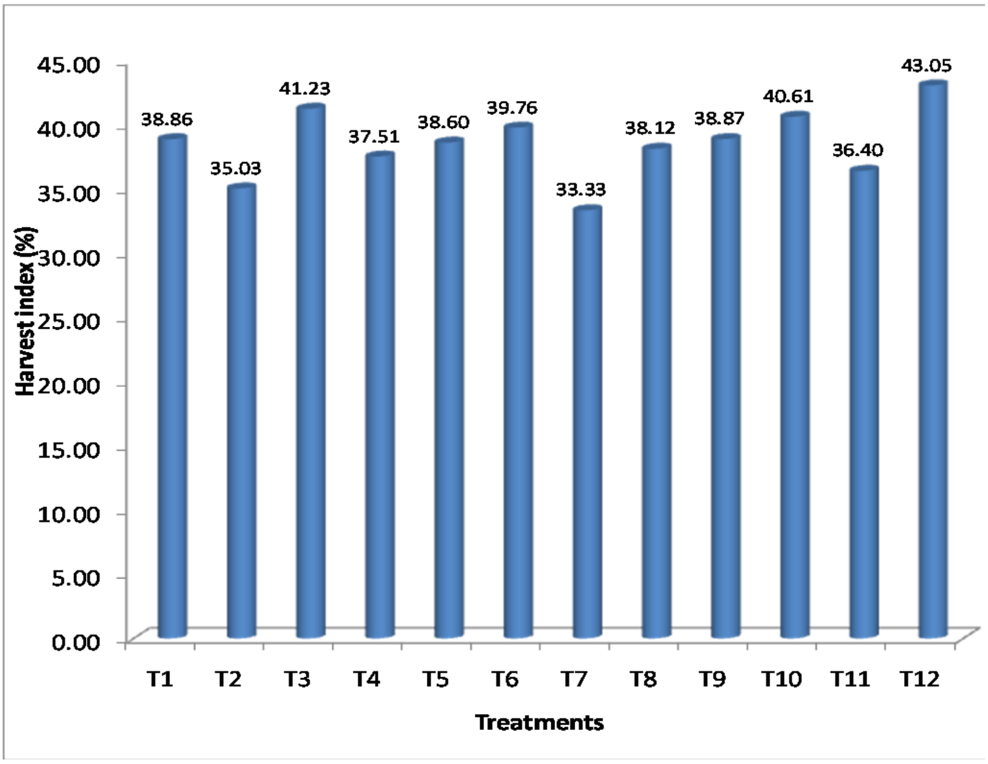
Similar results obtained by Naseem *et al*. (2009) who showed that application of water extract at pre-emergence + 25 DAS, 25 + 35 DAS and pre-emergence + 25 + 35 DAS increased the wheat yield significantly over control except pre-emergence + 25 + 35 DAS.

2.14 Effect on harvest index

There is significant variation observed on harvest index of wheat for *Brassica* varieties and their biomass (Appendix XXIV and Figure 9).

The T_{12} {*Brassica* (BARI Sarisha-15) with biomass of same variety} treatment showed the highest harvest index (43.05 %) which was statistically similar with T_2, T_3, T_4, T_5, T_6, T_8, T_9, T_{10} and T_{11} treatments.

The T_1 treatment (no *Brassica* + no biomass) resulted the lowest harvest index (35.03%) which was statistically similar with T_2, T_3, T_4, T_5, T_6, T_8, T_9,T_{10} and T_{11} treatments.



T_1 : No *Brassica* + no biomass (Control),
T_2 : No *Brassica* + biomass of 5 varieties
T_3 : *Brassica* (Tori 7) without biomass,
T_4 : *Brassica* (Tori 7) with biomass of same variety,
T_5 : *Brassica* (BARI Sarisha - 8) without biomass,
T_6 : *Brassica* (BARI Sarisha - 8) with biomass of the same variety ,
T_7 : *Brassica* (BARI Sarisha - 11) without biomass,
T_8 : *Brassica* (BARI Sarisha - 11) with biomass of the same variety,
T_9 : *Brassica* (BARI Sarisha - 13) without biomass ,
T_{10} : *Brassica* (BARI Sarisha - 13) with biomass of the same variety,
T_{11} : *Brassica* (BARI Sarisha - 15) without biomass,
T_{12} : *Brassica* (BARI Sarisha - 15) with biomass of the same variety.

Figure 9. Effect of *Brassica* variety and their biomass on harvest index of Wheat [SE = ± 1.330]

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 probable allelopahtic effect of *Brassica* varieties on wheat. The treatment of the experiment consisted of 12 treatments T_1 : No *Brassica* + no biomass (Control), T_2 : No *Brassica* + biomass of 5 varieties ,T_3 : *Brassica* (Tori 7) without biomass, T_4 : *Brassica* (Tori 7) with biomass of same variety, T_5 : *Brassica* (BARI Sarisha - 8) without biomass, T_6 : *Brassica* (BARI Sarisha - 8) with biomass of same variety , T_7 : *Brassica* (BARI Sarisha - 11) without biomass, T_8 : *Brassica* (BARI Sarisha - 11) with biomass of same variety, T_9 : *Brassica* (BARI Sarisha - 13) without biomass , T_{10} : *Brassica* (BARI Sarisha - 13) with biomass of same variety, T_{11} : *Brassica* (BARI Sarisha - 15) without biomass, T_{12} : *Brassica* (BARI Sarisha - 15) with biomass of same variety.

The experiment was laid out in a completely randomized block design following the principles of randomization with three replications. The sowing date of wheat was on 30th October, 2012. The unit plot size was 2.5m x 5m = 10 m^2.

Observations were made on wheat as weed population, dry weight of weed, plant height, number of leaves plant^{-1}, dry weight of wheat m^{-2}, number of effective tillers per linear meter, spike length, weight of 1000 grains, number of filled grains spike^{-1}, grain yield, straw yield, biological yield and harvest index. 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 and 60 days after sowing. Ten plants were randomly selected per plot for plant height at 25 DAS, 50 DAS, 70 DAS and at harvesting, plant dry weight at 30 DAS, 60 DAS and 90 DAS, number of leaves plant^{-1} at 25 DAS, 50 DAS, 70 DAS, spike length and number of filled grains spike^{-1} at harvest. Effective tillers were counted per linear meter from each plot. Thousand grains weight (g) was measured from sample seed. An area of 4.5 m^2 from each plot was harvested for grain yield and straw yield. Harvest index was calculated from grain yield and straw yield.

Soil status of previously cultivated with *Brassica* and *Brassica* biomass influenced weed population and weed dry weight. T_1 treatment (no *Brassica* + no biomass) resulted highest weed population at 30 DAS (230.80 m^{-2}) and at 60 DAS (300.70 m^{-2}) on the other hand T_6 treatment {*Brassica* (BARI Sarisha - 8) with biomass of the same variety} resulted the lowest weed population (100.40 m^{-2}) at 30 DAS and (181.30 m^{-2}) at 60 DAS.

At 30 DAS and 60 DAS the highest dry weight of weed (29.14 g m^{-2} & 57.51 g m^{-2}) in wheat field was observed in T_1 treatment (no *Brassica* + no biomass) and at 30 DAS the lowest dry weight of weed (8.33 gm^{-2}) in wheat field was observed in T_6 treatment {*Brassica* (BARI Sarisha - 8) with biomass of the same variety} while at 60 DAS lowest weed dry weight (22.98 g m^{-2}) recorded from T_{12} treatment {*Brassica* (BARI Sarisha - 15) with biomass of the same variety}.

Plant height of wheat varied significantly for *Brassica* varieties and their biomass at 50 DAS. Statistically no significant variation observed in plant height for *Brassica* varieties and their biomass at 25 DAS, 75 DAS and at harvest. At 50 DAS T_4 treatment {*Brassica* (Tori - 7) with biomass of the same variety} resulted highest plant height (66.93 cm) and the lowest plant height (61.07 cm) was obtained from the T_1 treatment (no *Brassica* + no biomass).

Leaf number $plant^{-1}$ of wheat varied significantly for *Brassica* varieties and their biomass at 25 DAS. Statistically no significant variation observed on leaf number $plant^{-1}$ of wheat for *Brassica* varieties and their biomass at 50 and 75 DAS. At 25 DAS, T_{12} treatment {*Brassica* (BARI Sarisha - 15) with biomass of the same variety} resulted the highest number of leaf $plant^{-1}$ (9.50) and lowest number of leaf $plant^{-1}$ of wheat (6.83) was observed in T_1 treatment (no *Brassica* + no biomass).

Significant variation observed in dry weight of plant at 30 DAS but there is no significant variation observed in plant dry weight at 60 DAS and 90 DAS for *Brassica* varieties and their biomass. At 30 DAS, the highest plant dry weight (16.03 gm^{-2}) was obtained from T_{12} treatments {*Brassica* (BARI Sarisha - 15) with biomass of the same variety} and the lowest plant dry weight (6.44 g m^{-2}) was obtained from T_1 treatment (no *Brassica* + no biomass).

Different *Brassica* variety, their previous cultivation in soil and their biomass significantly influenced number of effective tillers, filled grain $spike^{-1}$, grain yield, straw yield, husk yield, biological yield and harvest index of wheat.

The highest number of effective tiller per linear meter (42.67 m^{-1}) was found in T_{12} treatment {*Brassica* (BARI Sarisha - 15) with biomass of the same variety} and lowest number of effective tiller per linear meter (32.67 m^{-1}) was recorded in T_1 treatment (no *Brassica* + no biomass) whereas the highest number of non effective tiller per linear meter (9.33 m^{-1}) was recorded from T_3 treatment {*Brassica* (Tori - 7) without biomass} and lowest number of non effective tillers per linear meter (5.00 m^{-1}) was recorded from T_{12} treatment {*Brassica* (BARI Sarisha - 15) with biomass of the same variety}.

Spike length and thousand grain weight insignificantly influenced by different *Brassica* variety, their previous cultivation in soil and their biomass influenced. Statistically no variation observed among treatments, numerically T4 treatment {*Brassica* (Tori - 7) with biomass of the same variety} resulted the longest spike length (15.95 cm) and the shortest spike length (14.99 cm) observed in T_1 treatment (no *Brassica* + no biomass). Maximum thousand grain weight (46.86 g) obtained from T_{12} treatment {*Brassica* (BARI Sarisha - 15) with biomass of the same variety} numerically and the minimum value (42.13 g) recorded from T_1 treatment (no *Brassica* + no biomass). Statistically no variation observed among the treatments.

Maximum number of filled grain spike^{-1} (47.93) was recorded from T_2 treatments (no *Brassica* + biomass of 5 varieties) and minimum number of filled grain spike^{-1} (38.07) was obtained from T_1 treatment (no *Brassica* + no biomass). The highest grain yield (1.75 t ha^{-1}) was found in T_{12} treatment {*Brassica* (BARI Sarisha - 15) with biomass of the same variety} and the lowest grain yield (1.36 t ha^{-1}) was found from T_1 treatment (no *Brassica* + no biomass).

The highest straw yield (2.20 t ha^{-1}) was obtained from T_8 treatment {*Brassica* (BARI Sarisha - 11) with biomass of the same variety} and T_{11} treatment {*Brassica* (BARI Sarisha-15) without biomass} resulted lowest straw yield (1.63 t ha^{-1}). The highest husk yield (0.87 t ha^{-1}) was observed in T_7 {*Brassica* (BARI Sarisha-11) without biomass} treatment and the lowest husk yield (0.47 t ha^{-1}) was recorded from T_5 treatment {*Brassica* (BARI Sarisha-8) without biomass}

The T_8 treatment {*Brassica* (BARI Sarisha-11) with biomass of the same variety} resulted the highest biological yield (4.51 t ha^{-1}) and the lowest biological yield (3.58 t ha^{-1}) was recorded from T_1 treatment (no *Brassica* + no biomass).

There is significant variation observed on harvest index of wheat for *Brassica* varieties and their biomass. The T_{12} treatment {*Brassica* (BARI Sarisha-15) with biomass of same variety} showed the highest harvest index (43.08 %) and the T_1 treatment (no *Brassica* + no biomass) resulted the lowest harvest index (35.02%).

T_1 treatment (no *Brassica* + no biomass) resulted highest weed population at 30 DAS (230.80 m^{-2}) and 60 DAS (300.70 m^{-2}) also increased weed dry weight at 30 DAS (29.14 g m^{-2}) and 60 DAS (57.51 g m^{-2}) but reduced plant height at 50 DAS (61.07 cm), leaf number (6.83), plant dry weight at 30 DAS (6.44 gm^{-2}), effective tiller (32.67 m^{-1}), spike length (14.99 cm), filled grain spike^{-1} (38.07), grain yield (1.36 t ha^{-1}) and biological yield (3.58 t ha^{-1}) .

T_4 treatment {*Brassica* (Tori-7) with biomass of the same variety} resulted highest plant height (66.93 cm) at 50 DAS and spike length (15.95 cm).

T_6 treatment {*Brassica* (BARI Sarisha - 8) with biomass of the same variety} resulted lowest weed population at 30 DAS (100.40) and 60 DAS (181.30) also showed lowest dry weight of weed at 30 DAS (8.33 g m^{-2}) in the wheat field.

T_8 treatment {*Brassica* (BARI Sarisha - 11) with biomass of the same variety} found to increase straw yield (2.20 t ha^{-1}) and biological yield (4.51 t ha^{-1}).

T_{12} treatment {*Brassica* (BARI Sarisha - 15) with biomass of the same variety} significantly increased wheat leaf number $plant^{-1}$ (9.50), plant dry weight at 30 DAS (16.03 gm $^{-2}$), effective tiller (42.67 m^{-1}), thousand grain weight (46.86 gm), and grain yield (1.75 t ha^{-1}).

Considering the results of the present experiment, it can be concluded that weed suppression was quite positive with *Brassica* biomass and weed population not varied for varietal effect but is varied for biomass irrespective of variety. Specifically land with BARI Sarisha - 8 and biomass application reduced weed population at 30 DAS and 60 DAS by 35% and 21% in wheat field compared to that of T_1 treatment (no *Brassica* crop and no *Brassica* biomass) also reduced dry weight of weed at 30 DAS very effectively. Land with BARI Sarisha - 15 and biomass application reduced weed dry weight at 60 DAS and encouraged increasing yield of wheat and yield contributing characters.

It was also observed that the T_1 treatment gave 19%, 20% and 21% lower wheat grain yield compared to T_8 {*Brassica* (BARI sarisha - 11) with biomass of same variety}, T_6 {*Brassica* (BARI sarisha - 8) with biomass of same variety} and T_{12} {*Brassica* (BARI sarisha - 15) with biomass of same variety} respectively.

So, the treatments containing *Brassica* crop with *Brassica* biomass of the same variety not only controls weed in the wheat field but also encouraged yield contributing characters of wheat and gave higher grain yield than the treatments containing no *Brassica* and no *Brassica* biomass.

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

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APPENDICES

Appendix I. ANOVA for weed population at 30 DAS

Sources of variation	Degrees of freedom	Sum of squares	Mean square	F value
Replication	2	1540.984	770.492	3.8309 *
Treatment	11	41166.761	3742.433	18.6074 *
Error	22	4424.774	201.126	
Total	35	47132.519		

* Significant at 5% level

Appendix II. ANOVA for weed population at 60 DAS

Sources of variation	Degrees of freedom	Sum of squares	Mean square	F value
Replication	2	1065.722	532.861	1.0641 *
Treatment	11	35814.972	3255.907	6.5018 *
Error	22	11016.944	500.770	
Total	35	47897.639		

* Significant at 5% level

Appendix III. ANOVA for weed dry weight at 30 DAS

Sources of variation	Degrees of freedom	Sum of squares	Mean square	F value
Replication	2	21.764	10.882	1.0451 *
Treatment	11	1153.952	104.905	10.0753 *
Error	22	229.066	10.412	
Total	35	1404.782		

* Significant at 5% level

Appendix IV. ANOVA for weed dry weight at 60 DAS

Sources of variation	Degrees of freedom	Sum of squares	Mean square	F value
Replication	2	202.719	101.360	4.8828 *
Treatment	11	2984.760	271.342	13.0715 *
Error	22	456.683	20.758	
Total	35	3644.162		

* Significant at 5% level

Appendix V. ANOVA for plant height at 25 DAS

Sources of variation	Degrees of freedom	Sum of squares	Mean square	F value
Replication	2	41.653	20.827	4.4610 NS
Treatment	11	36.029	3.275	0.7016 NS
Error	22	102.709	4.669	
Total	35	180.391		

NS= Non-Significant

Appendix VI. ANOVA for plant height at 50 DAS

Sources of variation	Degrees of freedom	Sum of squares	Mean square	F value
Replication	2	5.041	2.520	0.2948 *
Treatment	11	85.396	7.763	0.9081 *
Error	22	188.086	8.549	
Total	35	278.523		

* Significant at 5% level

Appendix VII. ANOVA for plant height at 75 DAS

Sources of variation	Degrees of freedom	Sum of squares	Mean square	F value
Replication	2	68.916	34.458	1.5419 NS
Treatment	11	162.449	14.768	0.6608 NS
Error	22	491.644	22.347	
Total	35	723.009		

NS= Non-Significant

Appendix VIII. ANOVA for plant height at harvest

Sources of variation	Degrees of freedom	Sum of squares	Mean square	F value
Replication	2	38.17	19.08	1.957 NS
Treatment	11	90.807	8.255	0.7768 NS
Error	22	233.805	10.627	
Total	35	362.779		

NS= Non-Significant

Appendix IX. ANOVA for number of leaf plant^{-1} at 25 DAS

Sources of variation	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	2	2.042	1.021	1.9889 *
Treatment	11	20.854	1.896	3.6937 *
Error	22	11.292	0.513	
Total	35	34.188		

* Significant at 5% level

Appendix X. ANOVA for number of leaf plant^{-1} at 50 DAS

Sources of variation	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	2	24.389	12.194	3.7678 ^{NS}
Treatment	11	39.639	3.604	1.1122 ^{NS}
Error	22	71.278	3.240	
Total	35	135.306		

NS= Non-Significant

Appendix XI. ANOVA for number of leaf plant^{-1} at 75 DAS

Sources of variation	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	2	21.847	10.924	3.4175 ^{NS}
Treatment	11	35.910	3.265	1.0213 ^{NS}
Error	22	70.319	3.196	
Total	35	128.076		

NS= Non-Significant

Appendix XII. ANOVA for plant dry weight at 30 DAS

Sources of variation	Degrees of freedom	Sum of squares	Mean square	F value
Replication	2	45.336	22.668	1.0829 *
Treatment	11	237.209	21.564	1.0302 *
Error	22	460.496	20.932	
Total	35	743.040		

* Significant at 5% level

Appendix XIII. ANOVA for plant dry weight at 60 DAS

Sources of variation	Degrees of freedom	Sum of squares	Mean square	F value
Replication	2	12.676	6.338	0.0762 NS
Treatment	11	607.796	55.254	0.6639 NS
Error	22	1830.962	83.226	
Total	35	2451.434		

NS= Non-Significant

Appendix XIV. ANOVA for plant dry weight at 90 DAS

Sources of variation	Degrees of freedom	Sum of squares	Mean square	F value
Replication	2	166.223	83.111	0.5389 NS
Treatment	11	2055.475	186.861	1.2116 NS
Error	22	3393.039	154.249	
Total	35	5614.737		

NS= Non-Significant

Appendix XV. ANOVA for effective tillers linear m^{-1}

Sources of variation	Degrees of freedom	Sum of squares	Mean square	F value
Replication	2	115.167	57.583	2.6457 *
Treatment	11	363.000	33.000	1.5162 *
Error	22	478.833	21.765	
Total	35	957.000		

* Significant at 5% level

Appendix XVI. ANOVA for non-effective tillers linear m^{-1}

Sources of variation	Degrees of freedom	Sum of squares	Mean square	F value
Replication	2	1.065	0.528	0.2931 *
Treatment	11	48.972	4.452	2.4727 *
Error	22	39.611	1.801	
Total	35	89.639		

* Significant at 5% level

Appendix XVII. ANOVA for spike length

Sources of variation	Degrees of freedom	Sum of squares	Mean square	F value
Replication	2	4.472	2.236	3.2857 NS
Treatment	11	2.295	0.209	0.3066 NS
Error	22	14.972	0.681	
Total	35	21.740		

NS= Non-Significant

Appendix XVIII. ANOVA for filled grains $spike^{-1}$

Sources of variation	Degrees of freedom	Sum of squares	Mean square	F value
Replication	2	0.012	0.006	0.2600 *
Treatment	11	0.796	0.072	3.1695 *
Error	22	0.502	0.023	
Total	35	1.310		

* Significant at 5% level

Appendix XIX. ANOVA for thousand grains weight

Sources of variation	Degrees of freedom	Sum of squares	Mean square	F value
Replication	2	13.567	6.784	0.7159 NS
Treatment	11	120.747	10.977	1.1584 NS
Error	22	311.306	14.150	
Total	35	652.379		

NS= Non-Significant

Appendix XX. ANOVA for grains yield

Sources of variation	Degrees of freedom	Sum of squares	Mean square	F value
Replication	2	0.012	0.006	0.2600 *
Treatment	11	0.796	0.072	3.1695 *
Error	22	0.502	0.023	
Total	35	1.310		

* Significant at 5% level

Appendix XXI. ANOVA for straw yield

Sources of variation	Degrees of freedom	Sum of squares	Mean square	F value
Replication	2	0.179	0.090	1.8686 *
Treatment	11	1.091	0.099	2.0657 *
Error	22	1.056	0.048	
Total	35	2.326		

* Significant at 5% level

Appendix XXII. ANOVA for husk yield

Sources of variation	Degrees of freedom	Sum of squares	Mean square	F value
Replication	2	0.000	0.000	0.0135 *
Treatment	11	0.446	0.041	3.7914 *
Error	22	0.235	0.011	
Total	35	0.681		

* Significant at 5% level

Appendix XXIII. ANOVA for biological yield

Sources of variation	Degrees of freedom	Sum of squares	Mean square	F value
Replication	2	0.205	0.102	0.9199 *
Treatment	11	3.393	0.308	2.7702 *
Error	22	2.450	0.111	
Total	35	6.048		

* Significant at 5% level

Appendix XXIV. ANOVA for harvest index

Sources of variation	Degrees of freedom	Sum of squares	Mean square	F value
Replication	2	16.463	8.231	1.5501 *
Treatment	11	152.456	13.860	2.6099 *
Error	22	116.827	5.310	
Total	35	285.745		

* Significant at 5% level

PLATES

Plate 1. Sowing of *Brassica*

Plate 2. Harvested *Brassica*

Plate 3. Field view of Wheat at early stage

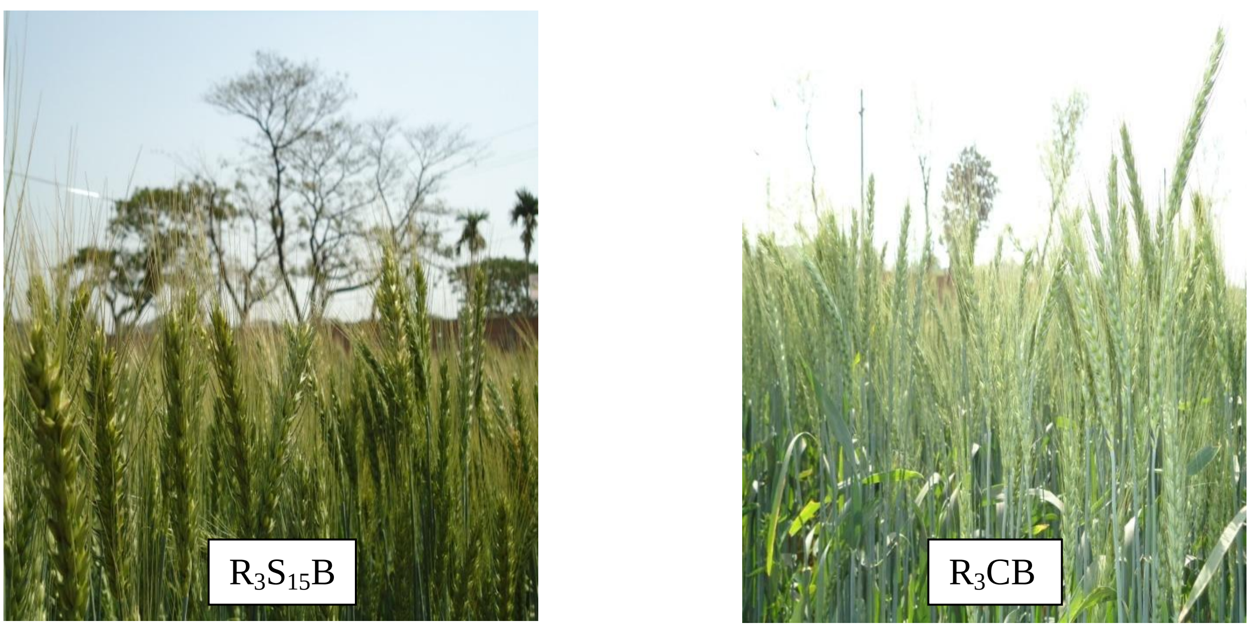

Plate 4. Wheat plant having different levels of *Brassica*

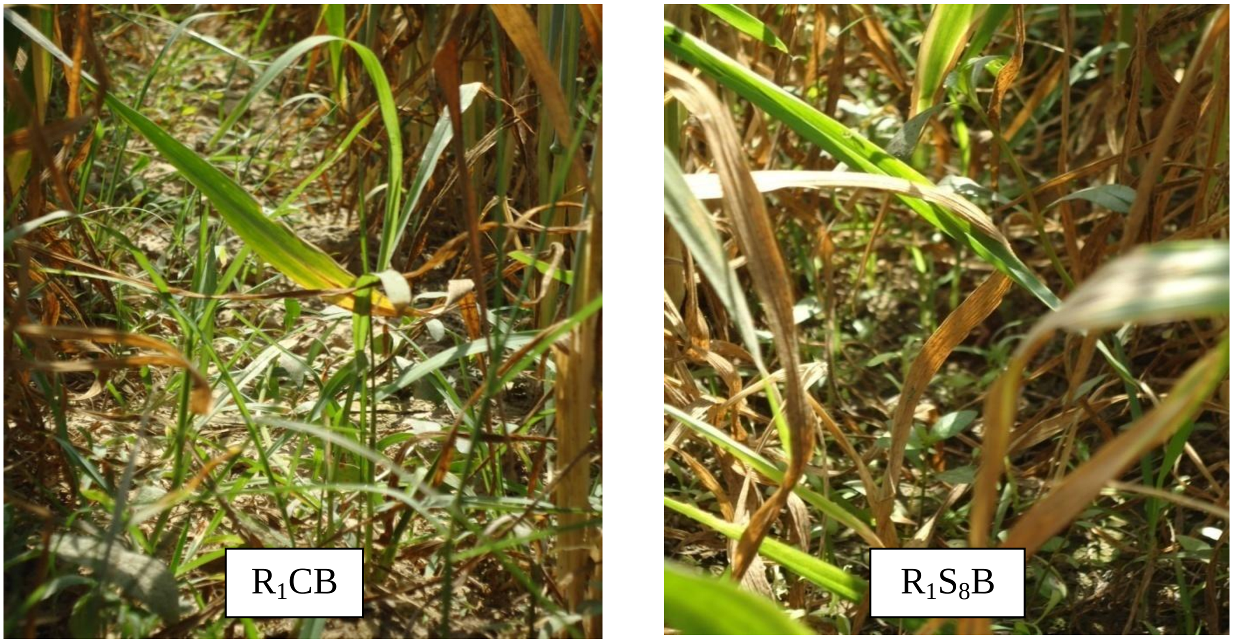

Plate 5. Variation of weed status

Plate 6. Field view of wheat at maturity stage

Plate: Harvesting of wheat

Plate 8: Field view of Wheat during harvesting