WEED CONTROL AND YIELD OF WHEAT AS AFFECTED BY BRASSICA ALLELOPATHY

A Thesis

By

ANISUR RAHMAN

Reg. No.: 04-01268

DEPARTMENT OF AGRONOMY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

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Approved By:

……………………………….. ………………………………….

(Dr. Parimal Kanti Biswas)
Professor
Supervisor

(Md. Sadrul Anam sarder)
Professor
Co-supervisor

……………………………………….

Professor Dr. Md. Fazlul Karim
Chairman
Examination Committee

DEDICATED TO MY ADORED PARENTS

DEPARTMENT OF AGRONOMY
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207
PABX: 9110351 & 9144270-79

CERTIFICATE

This is to certify that the thesis entitled **"WEED CONTROL AND YIELD OF WHEAT AS AFFECTED BY BRASSICA ALLELOPATHY"** 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 ***ANISUR RAHMAN,*** Registration. No. 04-01268, under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.

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

Dated:

Dhaka, Bangladesh

(Dr. Parimal Kanti Biswas)
Professor
Supervisor

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WEED CONTROL AND YIELD OF WHEAT AS AFFECTED BY *Brassica* ALLELOPATHY

By

ANISUR RAHMAN

ABSTRACT

The experiment was conducted at the Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka from November, 2008 to March, 2009 to find out the allelopathic effect of *Brassica* biomass on weed control and yield of wheat. The treatment of the experiment consisted of 2 levels of field status viz. fallow land (C_1) and field with *Brassica* (C_2); 2 levels of maturity viz. 25 days old *Brassic*a (M_1) and 35 days old *Brassica* (M_2); and 3 levels of *Brassica* biomass amount viz. 0 kg biomass m^{-2} (B_1), 0.5 kg biomass m^{-2} (B_2) and 1.0 kg biomass m^{-2} (B_3). Maximum weed population at 30 DAS (165 m^{-2}) and at 60 DAS (291 m^{-2}), dry wt. of weeds at 30 DAS was found in the plots having no biomass. The highest dry weight of weed at 60 DAS was found for the field status from fallow land (107.77 gm^{-2}), 25 days old *Brassica* (78.80 gm^{-2}) & 0 kg biomass application (89.94 gm^{-2}). The highest grain yield was found from *Brassic*a fields (2.68 t ha^{-1}), 35 days old *Brassica* biomass (2.59 t ha^{-1}) & 1.0 kg biomass application (2.71 t ha^{-1}). The interaction effect of field status and *Brassica* biomass concentration showed significant result on weed population (80.33 m^{-2}), dry weight of weed (39.74 g m^{-2}), plant height (33.98 cm), number of effective tillers linear m^{-1} (84.67), spike length (16.09 cm), number of filled grain $spike^{-1}$ (50.93), number of leaves $plant^{-1}$ (10.53), weight of 1000 grains (41.22 g), grain yield (2.83 t ha^{-1}) and straw yield (4.08 t ha^{-1}).The lowest weed population (124.0 m^{-2}) and dry weight of weed (39.11 gm^{-2}) at 60 DAS was found from the field with *Brassica* field and 25 days old biomass @ 1.0 kg m^{-2}. The highest thousand grain weight (41.84 g) was found from the field with 35 days old *Brassica* application @ 0.50 kgm^{-2}. The maximum grain yield (2.86 t ha^{-1}) was found from the field with 35 days old *Brassica* biomass application @ 1.0 kgm^{-2}. 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. On the other hand, 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.

∗A thesis presented for partial fulfillment of MS Degree

♣MS student, Dept. of Agronomy, SAU, Dhaka-1207

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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). 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 on going 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 as well as soil, water and environment hazards. Managing croplands according to nature's principles will reduce weed problems. Some crops are especially useful because they have the ability to suppress other plants that attempt to grow around to them. 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). 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 and 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 *et al*. (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. Yenish and Worsham (1993) also reported highest weed control by rye application. Anon (1993) reported allelopathic effect of rapeseed and showed 90% reduction of yellow nutsedge on sweet potatoes. 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 to study the role of *Brassica* having different amount and different maturity 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 different ages of *Brassica* biomass to control different weeds in wheat field.
3. To find out the optimum amount 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. 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 Allelopathic effect of crop biomass

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 johnsongrass 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.

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.

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 dhan 37, BRRI dhan 30 and BRRI dhan 38, 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.*

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.

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.

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.

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.

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

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

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.

Xuan *et al.* (2005 a) 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.

Xuan *et al.* (2005 b) 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.

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.

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.

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.

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

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

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.

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.

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.

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.

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

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.

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.

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.

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.

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.

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

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

Mersie and Singh (1987) examined the allelopathic effect of dried lantana shoot residues on wheat, corn, soybean, Virginia pepperweed and velvetleaf on growth over a 30-day period. Significant differences in the growth of the test species were observed. Corn was the most sensitive and wheat was least affected by lantana residues. The other three species were intermediate in their growth response to lantana. Shoot lengths were affected in corn and velvetleaf while root length was reduced in all species except wheat. The shoot dry weights of wheat and soybean were not reduced by lantana residues. In the other three species there was a significant reduction of shoot dry weight due to lantana. The root dry weights of all the five species were reduced by lantana residue.

Daar (1986) said that rye residue contained generous amounts of allelopathic chemicals. When rye is killed in place and left undisturbed on the soil surface, these chemicals leach out and prevent germination of small-seeded weeds. Weed suppression is effective for about 30–60 days.

Qasem and Abu-Irmaileh (1985) examined the allelopathic effect of *Salvia syriaca* L. (Syrian sage) against wheat in glasshouse and laboratory experiments. The germination of wheat grains was delayed, and the development of wheat seedlings was found to be decreased in laboratory experiments by both shoot and rhizome extract. The inhibitory effect of both extracts was most pronounced at 20°C compared with 10 or 15°C. Shoot extracts had more drastic effects than the rhizome extract on germination percentage, shoot and root lengths. In glasshouse experiments fresh and dried shoot of *S. syriaca* added to soil drastically decreased germination and development of wheat.

Shilling *et al.* (1985) reported that a surface mulch of desiccated rye in a no-till system reduced aboveground biomass of common lambsquarters by 99%, redroot pigweed by 96%, and common ragweed by 92% compared to an unmulched tilled control.

Rose *et al.* (1984) experimented on 280 soybean cultivars and invented that soybean cultivars of later maturity tended to compete more effectively with weeds. Twenty soybean cultivars of varying competitive ability were selected and grown in the greenhouse during 1981 and 1982 to determine the importance of allelopathy in competing with weeds. Exudates from roots of soybean cultivars grown in sand reduced the dry weight of 4-week-old velvetleaf plants an average of 15%, but foxtail millet was not inhibited. Incorporation of 1% ground soybean dry matter into Sharpsburg silty clay loam inhibited germination and dry weight of greenhouse grown velvetleaf an average of 46% each. Foxtail millet germination and dry weights were reduced an average of 82 and 65%, respectively. Undiluted soybean plant extracts of all cultivars tested slowed the germination and dry weight accumulation of 6-day-old velvetleaf and foxtail millet, but dilution of the extracts caused quite variable responses.

2.2 Allelopathic effect of previous crop

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.

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.

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%.

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.

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.

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.

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.

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.

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.

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

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. Potato following rapeseed yielded 25% and 17% more total tuber weight than potato following sudangrass in 1992 and fellow in 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.

Leather (1987) conducted field studies to determine if season long weed control could be achieved by combining the use of an herbicide with the natural allelochemicals produced by cultivated sunflower (*Helianthus annuus* L.). The weed biomass was reduced equally in plots planted with sunflowers, whether or not the herbicide was applied in each of 4 years. Weed control diminished the second year in all plots that received the same treatments as had been applied the previous year. This diminished efficacy was attributed to reduced emergence of sunflower (13.5 to 45.2 percent) in second-year plots, as a result of autotoxicity from sunflower crop residues remaining after the first-year harvest.

2.3 Allelopathic effect of maturity of biomass

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.

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.

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.

Bhatt and Todaria (1990) tested the allelopathic effects of *Adina cordifolia, Alnus nepalensis, Celtis australis* and *Prunus cerasoides* by growing crops of *Eleusine coracana, Glycine max* and *Hordeum vulgare* on top soil, rhizosphere soil from the plantation of these trees, and on field soil either mulched with dry leaves or irrigated with aqueous leaf extracts of the agroforestry tree species. Germination percentage, shoot length, root length and dry matter production and pigment contents of crops were depressed by agroforestry tree crops. Maximum reduction in germination percentage, root-shoot length and dry matter production was obtained with experimental garden soil mulched with dry leaves of trees and by the effect of *Adina cordifolia* followed by *P. cerasoides, H. vulgare* proved most susceptible and *E. coracana* highly resistant to these tree-top interactions.

2.4 Allelopathic effect of concentration of crop biomass

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

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.

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). Weed species present in the experimental area were *Trianthema portulacastrum, Cyprus rotundus, Dactyloctenium aegyptium, Cynodon dactylon* and *Cleome viscosa.* Combination of sorghum + sunflower + brassica each at 18 L ha^{-1} and 1/3 dose of atrazine (0.167 kg ha^{-1}) reduced total weed dry weight by 86 to 75% at 45 DAS respectively. Maize yield increased by 48 to 51 % by the combination treatment of sorghum + sunflower + brassica water extracts each at 18 L ha^{-1} and with 1/3 dose of atrazine (0.167 kg ha^{-1}) as early post emergence (15 DAS) over the control, respectively, and yields were equal to the yields obtained from the recommended rate of S-metolachlor + atrazine and atrazine alone.

Mahmood *et al*. (2008 b) 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. 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.

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.

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.

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.

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.

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.

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

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

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.

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

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

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

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.

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.

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.

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.

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.

Moyer and Huang (1993) conducted an experiment to observe the effect of crop residue on germination and growth of weeds. In this experiment they used the aquas extract of six different crop residue which were Canola (*Brassica napus* L.), Rye (*Secale cereale* L.), Barley (*Hordeum vulgare* L.), Oats (Avena sativa L.), Indian Head lentil (*Lens culinaris* Medic), and Wheat (*Triticum aestivum* L.). They noticed that crop extract also reduce germination and growth of other crops. Wheat germination was reduced by lentil, oat, and canola extracts at 4%. Wheat root growth was suppressed by all plant extracts except wheat at 1 %. None of the extracts inhibited shoot growth at 1 %. At 2% extracts of lentil, oat, and canola inhibited wheat shoot growth, and at 4% all plant extracts inhibited shoot growth.

CHAPTER 3

MATERIALS AND METHODS

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

3.1 Location

The experiment was carried out during rabi season (October to March) of 2008–09, 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 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 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}.

3.4.2 Description of wheat cultivar Prodip

Prodip (BARI gom-24) is a modern wheat variety released by BARI in 2005. It is semi-dwarf (95–100 cm) plant with good tillering ability. It produces generally 3-4 tillers $plant^{-1}$. The leaves are broad, recurved and light green in color. Flag leaves are also broad and droopy. The plants are light green in color with weak glaucosity in the spike, culm and flag leaf sheath. Lower glume beak is very long (>15.0 mm) and the lower glume shoulder shape is elevated and broad with numerous spicules on the beak. The total life duration ranges from 102-110 days. The grains are white and large with 1000-grain ranges from 48-55 g. The variety is resistant to leaf rust and highly tolerant to *Bipolaris* leaf blight. The variety is heat tolerant and is best suited under both optimum and late planting for rice-wheat cropping system. It is a high yielding variety, under normal environmental condition, the variety yields 4300-5100 kg/ha. It can out-yield the popular variety Kanchan both in optimum planting and late planting and can also be grown successfully throughout the country except in saline area.

3.5 Experimental treatments

There were three sets of treatments in the experiment. The treatments were field status, maturity and concentration of *Brassica* biomass. They are shown as below:

Factor A. Main plot: Field status (2 levels):

i. C_1: Fallow land ii C_2: Field with *Brassica*

Factor B. Sub-plot: Maturity of *Brassica* (2 levels):

i. M_1: 25 days old *Brassica*
ii. M_2: 35 days old *Brassica*

Factor C. Sub sub-plot: Amount of *Brassica* biomass (3 levels)

i. B_1: 0 kg biomass/m^2
ii. B_2: 0.5 kg biomass/m^2
iii. B_3: 1.0 kg biomass/m^2

3.6.1 Layout of *Brassica* spp.

The experimental unit was divided into three blocks. Each block was divided into two main plots of which one plot was sown by BARI Sarisha-15 and the other kept fallow. The main plot with *Brassica* was further divided into two sub-plot where first sowing was done at 01 November and second was at 11 November. The block was 23 m × 7 m in size with 1m distance between blocks. The layout of the experiment is shown in Figure 1. The *Brassica* plants were uprooted on 06 November for incorporate in wheat field as per treatments.

3.6.2 Layout of main experiment

The experiment was laid out in split split-plot design with three replications. The experimental unit was divided into three blocks each of which representing a replication. Each block was divided into two main plots (one fallow and one with *Brassica*). Each main plot was further divided into 2 unit plots or sub-plots for spreading *Brassica* biomass with 25 and 35 days old. Then two sub-plots were further divided into three sub sub-plots for *Brassica* biomass with 3 different concentrations. So, the total number of unit plots in the entire experimental plot was 3 ×2 ×2×3 = 36. Size of each unit plot was 3 m × 3 m = 9 m^2. The distance maintained between two sub-plot, sub sub-plot and between blocks was 1m (Figure 2).

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, 2008 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 1 November 2008 according to design immediately after final land preparation. The *Brassica* variety BARI sarisha 15 was sown in two times following the date on 01 November and 11 November consecutively. After harvesting the *Brassica* at their 25 DAS (26.11.08) and 35 DAS (06.12.08) the land was again prepared as before. The final land preparation was done on December 7, 2008 and layout was done as per experimental design. Individual plots were cleaned and finally leveled with the help of wooden plank. The collected *Brassica* biomass were incorporated to the soil during final land preparation following experimental design.

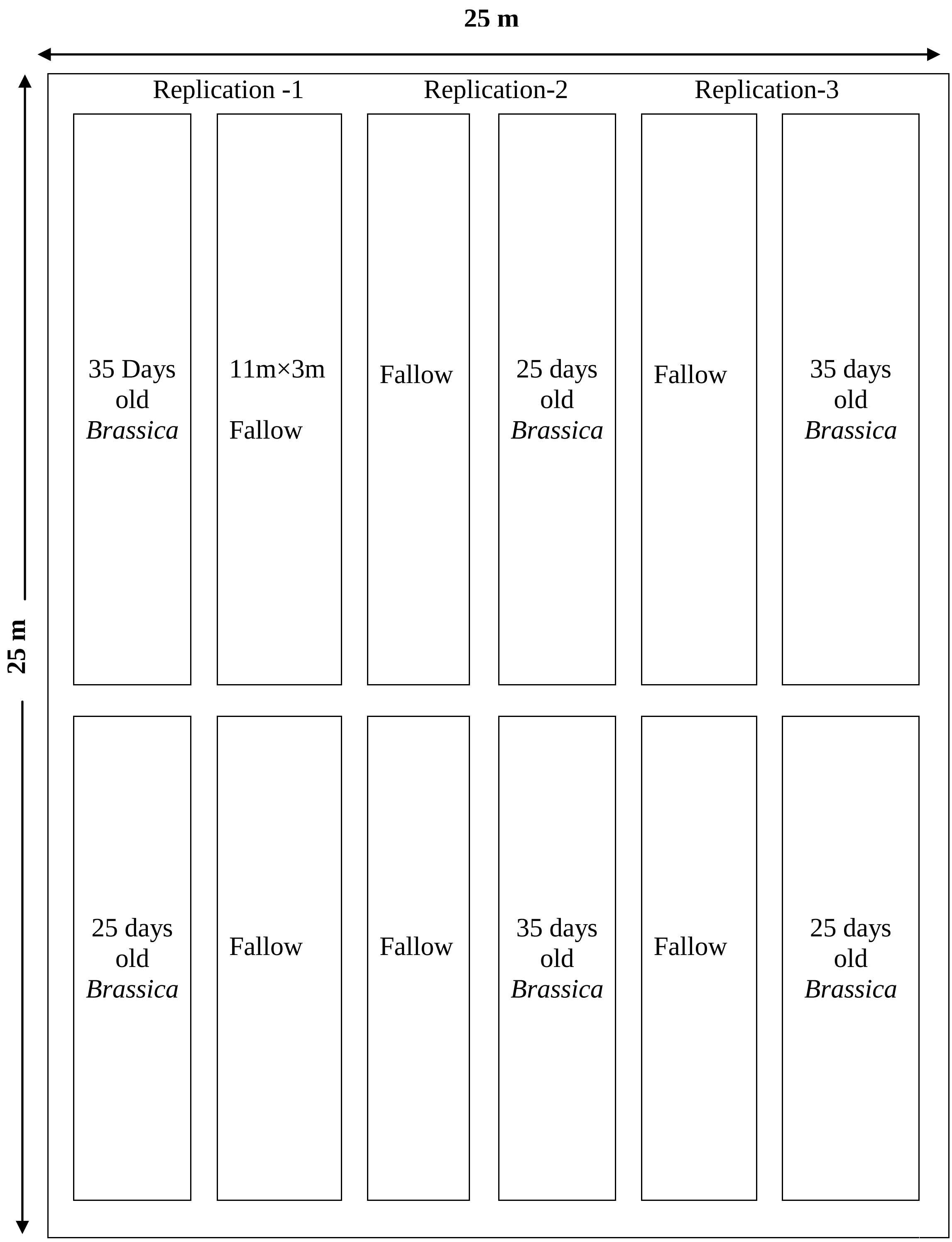


Figure 1. Lay out of the experimental plot (*Brassica*)

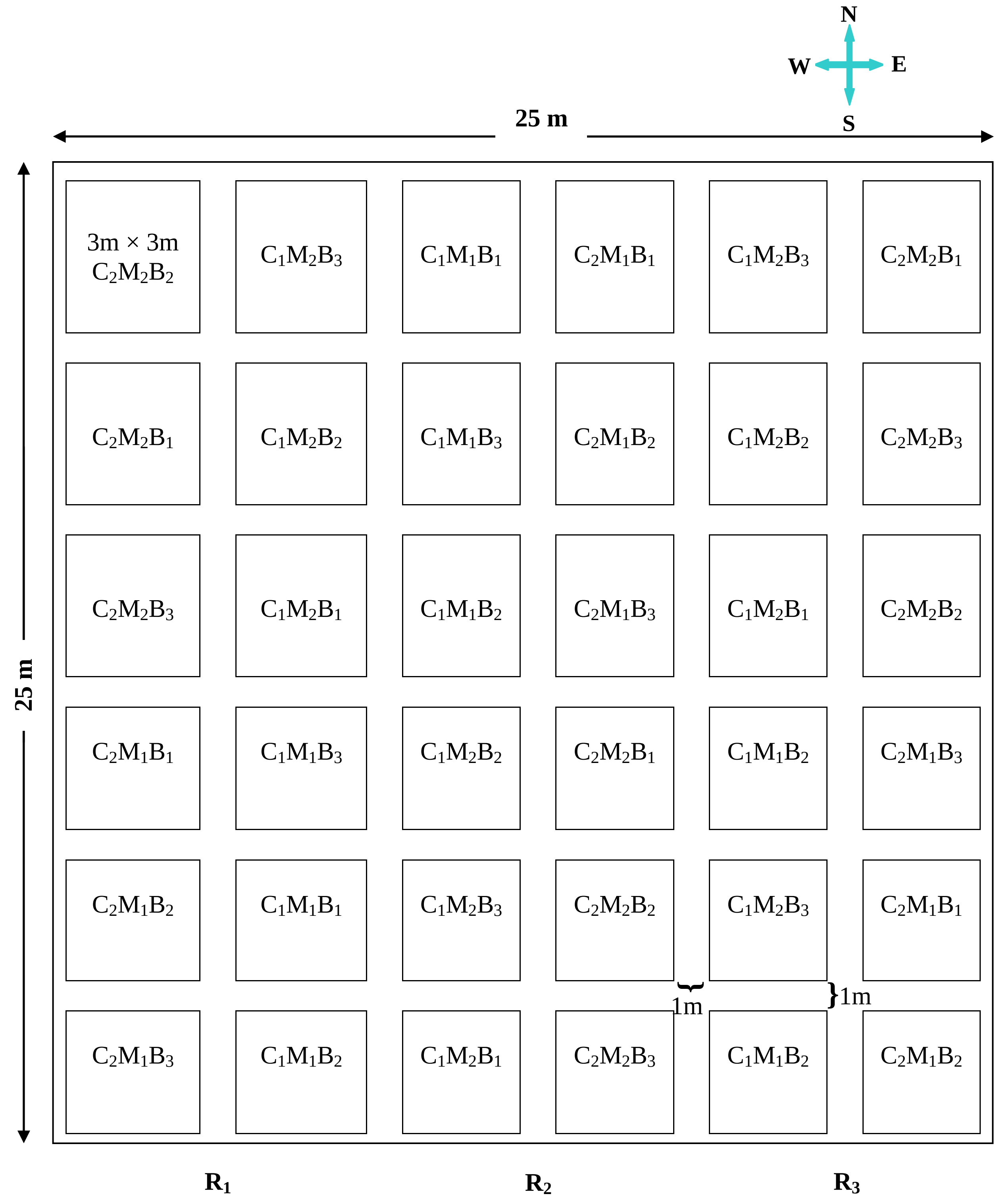


Figure 2. Layout of the experimental plot (wheat field)

Main Plot:
Field status:
C_1: Fallow land
C_2: Field with *Brassica*

Sub Plot:
Maturity of *Brassica:*
M_1: 25 days old *Brassica*
M_2: 35 days old *Brassica*

Sub Sub-plot:
Amount of *Brassica* biomass:
B_1: 0 g biomass/m^2
B_2: 0.5 kg biomass/m^2
B_3: 1.0 kg biomass/m^2

3.7.2 Fertilizer application

The *Brassica* field was fertilized with urea, triple super phosphate (TSP), muriate of potash (MOP), gypsum, zinc sulphate and boric acid at the rate of 250-180-100-180-10 and 5 kg ha^{-1} respectively. Half of the urea, TSP, MOP, gypsum, zinc sulphate and boric acid were applied at final land preparation.

The main experimental field was fertilized with urea, triple super phosphate (TSP), muriate of potash (MOP), gypsum and zinc sulphate at the rate of 264, 220, 168, 168 and 5.56 kg ha^{-1} respectively. The whole amount of triple super phosphate (TSP), muriate of potash (MOP), gypsum and zinc sulphate 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 (BARI Sarisha 15) were collected from Oilseed Research Centre, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. At good tilth condition seeds were sown on 1st and 11th November, 2008. 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. Prodip) 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 7th December, 2008 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, 2009. Samples were collected from different places of each plot leaving undisturbed middle six rows in the centre. The selected sample plants were then tagged and carefully carried out to the Agronomy field laboratory in order to collect data. Plants of central 6 m^2 and the rest crop was harvested separately plot-wise, bundled and tagged. 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
2. Number of tillers m^{-1} (linear)
3. Number of leaves $plant^{-1}$
4. Dry weight of plants
5. Spike length
6. Number of spikelets $spike^{-1}$
7. Number of filled grains $spike^{-1}$
8. 1000 grain weight
9. Grain yield
10. Straw yield
11. Harvest index

3.8.1.1 Weed population

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

3.8.1.2 Dry weight of weed biomass

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

3.8.2 Yield contributing characters and yield of wheat

3.8.2.1 Plant height

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

3.8.2.2 Number of effective tillers linear m^{-1}

The total number of spikelet bearing tillers linear m^{-1} was counted. Data were recorded randomly from the inner rows of each plot at the time of harvest.

3.8.2.3 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 from inner rows plants of each plot. Data was recorded at harvest time. Mean data was expressed in centimeter (cm).

3.8.2.4 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.

3.8.2.5 Number of spikelets spike^{-1}

Data on the total number of spikelets spike^{-1} was counted. Ten spike bearing plants were randomly selected and the average data were collected from the inner rows of each plot except harvest area during the time of harvest.

3.8.2.6 1000 grain weight

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

3.8.2.7 Grain yield

Inner 6 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}.

3.8.2.8 Straw yield

Inner 6 m^2 areas of each plot were harvested from which straw weight was determined after threshing and drying and finally converted them into t ha^{-1}.

3.8.2.9 Harvest index

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

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

3.9 Statistical analysis

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

CHAPTER 4

RESULTS AND DISCUSSION

The present experiment was conducted to study the allelopathic effect of different ages and concentration of *Brassica* biomass on weed control and yield of wheat. The analysis of variance data on different crop and yield contributing characters as well as yield of wheat as influenced by different levels of *Brassica* biomass has been presented and interpreted in this chapter. The results on main and combined effect of crop, biomass and maturity are also presented and discussed under this section.

4.1 Effect of previous field status

4.1.1 Weed population

There were no significant variations of weed population observed for different field status e.g., with *Brassica* and without *Brassica* (Appendix A.1). The numerical number of weed population m^{-2} was maximum (154.44) in fallow land and the minimum (102.00) with *Brassica* plants on 30 DAS. In similar way, maximum weed population m^{-2} (281.11) was found from fallow land and the minimum population m^{-2} (173.78) from the land with *Brassica* on 60 DAS (Table 1). Previous field condition with *Brassica* plant reduced weed population by 51.41% and 61.76% at 30 and 60 DAS respectively compared to fallow land condition. Similar result was found by Uremis *et al*. (2009) who reported that the allelopathic potential of residues of some *Brassica* species suppressed johnsongrass under both laboratory and field conditions. The result was also in agreement with the findings of Boydston (2008) who reported that brassicaceae cover crops suppress weeds due to fast emergence and vigorous competitive growth during fall establishment and allelopathic substances released during degradation of the cover crop residues. Maiksteniene and Arlauskiene (2006) also showed that under sown intercrops (*Trifolium pratense* L., *Lolium multiflorum* Lam., *Dactylis glomerata* L.), reduced the number of weeds in cereals (on average 13.90%).

Table 1. Effect of field status on weed population, weed dry weight and plant height of wheat

Treatments	Weed population (No. m^{-2})		Weed dry wt. (gm^{-2})		Plant height (cm)	
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	At harvest
C_1	154.44	281.11	13.28	107.77a	28.96	88.10
C_2	102.00	173.78	5.92	45.61b	32.57	90.25
SE	NS	NS	NS	5.1962	NS	NS
CV (%)	38.16	23.17	40.70	25.81	10.938	3.22

C_1 = Previous fallow land C_2 = Previous land with *Brassica*
NS = Not significant

4.1.2 Weed dry weight

Variation in weed dry weight of wheat crops with or without *Brassica* field condition was statistically insignificant at 30 DAS but significant at 60 DAS (Appendix A.2). The numerically maximum weed dry weight (13.28 g m^{-2}) and the minimum (5.92 g m^{-2}) at 30 DAS was found in fallow land at 30 DAS but the highest dry weight (107.77 g m^{-2}) and the lower (45.61 g m^{-2}) was observed at 60 DAS (Table 1) in the land with *Brassica*. The dry weight of weed in *Brassica* field condition was 44.57% and 42.32% lower at 30 and 60 DAS respectively compared to previous fallow land condition. This result was similar with the findings of Cheema *et al*. (2008) who concluded that inclusion of allelopathic crops in rotation systems for weed suppression by early post-emergence application of the mixture of sorghum, sunflower, *Brassica* or mulberry water extracts suppressed total weed dry weight. Tawaha and Turk (2003) also stated that soil incorporation of fresh black mustard roots and both roots and shoots reduced wild barley germination, plant height and weight when compared with a no-residue control.

4.1.3 Plant height

No significant variations were found for plant height of wheat having previous field condition with or without *Brassica* (Appendix A.3). The result showed that the maximum plant height of wheat (32.57 cm) was recorded in wheat land with *Brassica* and the minimum (28.96 cm) was recorded in fallow land at 30 DAS (Table 1). Similarly, the maximum plant height (90.25 cm) was found from land with *Brassica* and the minimum (88.10 cm) from fallow land at harvest. Similar results were found by Maharjan *et al.* (2007) who 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.).

4.1.4 Effective tillers linear m^{-1}

No significant variations were observed in effective tillers linear m^{-1} for different field condition (Appendix A.4) though the maximum effective tillers linear m^{-1} (78.78) was recorded from fallow land and the minimum (77.61) was found in the land with *Brassica* (Table 2).

Table 2. Effect of previous field status on effective tillers linear m^{-1}, spike length, number of filled grains $spike^{-1}$ and number of leaves $plant^{-1}$

Treatments	Effective tillers linear m^{-1}	Spike length (cm)	No. of filled grains $spike^{-1}$	No. of leaves $plant^{-1}$
C_1	78.78	15.33	44.36	8.89
C_2	77.61	15.96	50.07	9.51
SE	NS	NS	NS	NS
CV (%)	10.18	2.85	5.61	17.39

C_1 = Previous fallow land C_2 = Previous land with *Brassica*
NS = Not significant

4.1.5 Spike length

Statistically insignificant variations in spike length of wheat plant was found for different crop lands (Appendix A.5) though the longer spike length (15.96 cm) was observed in crop land with *Brassica* and the shorter (15.33 cm) was in fallow land (Table 2).

4.1.6 Number of filled grains spike^{-1}

There was no significant variation for number of filled grains per spike for different crop lands (Appendix A.6). The maximum number of filled grains per spike (50.07) was recorded from the crop land with *Brassica* and the minimum (44.36) was from fallow land (Table 2).

4.1.7 Number of leaves plant^{-1}

Statistically insignificant variations in number of leaves per plant at 30 DAS was observed among the crop lands (Appendix A.7) though the maximum number of leaves (9.51) per plant was found in the land with *Brassica* and the minimum (8.89) from fallow land (Table 2).

4.1.8 Weight of 1000 grains

Statistically significant variations in weight of thousand grains for different crop lands were observed (Appendix A.8). The higher weight of thousand grains (40.52 g) was recorded in the crop land with *Brassica* and the lower (37.26 g) was from fallow land (Table 3). The previous land with *Brassica* showed 8.04% higher grain weight compared to that of fallow land condition.

Table 3. Effect of previous field status on weight of 1000 grains, grain yield, straw yield and harvest index of wheat

Treatments	Weight of 1000 grains (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
C_1	37.26 b	2.38 b	3.18 b	42.96 a
C_2	40.52 a	2.68 a	3.89 a	41.71 b
SE	0.2481	0.0033	0.0773	0.1342
CV (%)	4.75	4.71	12.54	4.67

C_1 = Previous fallow land C_2 = Previous land with *Brassica*
NS = Not significant

4.1.9 Grain yield

There was significant variation for grain yield (t ha^{-1}) for different crop land (Appendix A.9). The higher grain yield of wheat (2.68 t ha^{-1}) was found from the crop land with *Brassica*. The lower grain yield (2.38 t ha^{-1}) was recorded from the fallow land (Table 3). These results was also in agreement with the findings of Cheema *et al*. (2008) who concluded that inclusion of allelopathic crops in rotation systems for weed suppression by early post-emergence application of the mixture of sorghum, sunflower, *Brassica* or mulberry water extracts suppressed total weed dry weight and enhanced yield of wheat, maize, cotton and rice. Boydston and Hang (1995) also concluded that Potato following rapeseed yielded 25% and 17% more total tuber weight than potato following sudangrass in 1992 and fallow in 1993 respectively.

4.1.10 Straw yield

Statistically significant variation in straw yield was observed for different crop lands (Appendix A.10). The higher straw yield (3.89 t ha^{-1}) was observed from the land with *Brassica* and the lower straw yield (3.18 t ha^{-1}) was found from fallow land (Table 3). Statistically dissimilar result was found by Mirabelli *et al.* (2004) who concluded that 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 50.60 vs 46.0 t ha^{-1}) tuber FM, respectively.

4.1.11 Harvest index

Significant variation in harvest index for different crop lands were observed (Appendix A.11). The result expressed that the higher harvest index (42.96%) was recorded from fallow land and the lower (41.71%) was from the land with *Brassica* (Table 3).

4.2 Effect of *Brassica* maturity

4.2.1 Weed population

No significant variation of weed population in wheat field was observed for *Brassica* maturity at 30 DAS but significant variation in weed population was found for *Brassica* maturity at 60 DAS (Appendix A.1). The maximum number of weeds (136.33m^{-2}) was found with 35 days old *Brassica* biomass and the minimum (120.11 m^{-2}) from 25 days old *Brassica* biomass at 30 DAS. The higher number of weed population (246.67 m^{-2}) was found with 35 days old *Brassica* biomass and the lower (208.22 m^{-2}) from 25 days old *Brassica* biomass at 60 DAS (Table 4). Chandra Babu and Kandasamy (1997) reported that aqueous leachate of fresh leaves of eucalyptus significantly suppressed the establishment of vegetative propagules and early seedling growth of the weeds.

Table 4. Effect of *Brassica* biomass maturity on weed population, dry weight of weed and plant height of wheat

Treatments	Weed population (No. m^{-2})		Dry wt. of weed (g m^{-2})		Plant height (cm)	
	30 DAS	60 DAS	30 DAS	60 DAS	30DAS	At harvest
M_1	120.11	208.22b	9.44	78.80 a	28.96	88.10
M_2	136.33	246.67a	9.76	74.58 b	32.57	90.25
SE	NS	10.093	NS	3.58	NS	NS
CV (%)	38.16	23.17	40.70	25.81	10.938	3.22

M_1 = 25 days old *Brassica* biomass M_2 = 35 days old *Brassica* biomass
NS = Not significant

4.2.2 Weed dry weight

There was no significant variation in weed dry weight observed for *Brassica* maturity at 30 DAS. Variation in weed dry weight was observed for *Brassica* maturity at 60 DAS (Appendix A.2). At 30 DAS, the maximum weed dry weight (9.76 g m^{-2}) was observed with 35 days old *Brassica* biomass and the minimum (9.44 g m^{-2}) was found with 25 days old *Brassica* biomass. At 60 DAS, the significantly higher dry weight of weed (78.80 g m^{-2}) was recorded with 25 days old *Brassica* biomass and the minimum (74.58 g m^{-2}) was with 35 days old biomass (Table 4). Chandra Babu and Kandasamy (1997) also reported that leachate of fresh leaf cuttings of eucalyptus tree had growth inhibitory effect on Bermuda grass than the leachate of dried leaves of eucalyptus.

4.2.3 Plant height

Statistically insignificant variation in plant height of wheat was observed for *Brassica* maturity both at 30 DAS and at harvest (Appendix A.3). The numerical maximum plant height (32.57 cm) was recorded with 35 days old *Brassica* biomass and the minimum (28.96 cm) with 25 days old biomass at 30 DAS and at harvest, the maximum plant height (90.25 cm) was found with 35 days old *Brassica* biomass and the minimum (88.10 cm) was with 25 days old biomass (Table 4). Chaichi and Edalati-Fard (2005) studied the allelopathic effects of chickpea root extracts on germination and early growth of crops in rotation and reported that the crop height followed an increasing trend as they were sown later after physiological ripening of chickpea lines.

4.2.4 Effective tillers Linear m^{-1}

No significant variation was found in number of effective tillers linear m^{-1} for *Brassica* maturity (Appendix A.4). Though the maximum number of effective tillers linear m^{-1} (79.39) was noted with 35 days old *Brassica* biomass and the minimum (77.00) was with 25 days old biomass (Table 5).

Table 5. Effect of maturity on effective tillers m^{-1}, spike length, filled grains spike^{-1} and leaves plant^{-1} of wheat

Treatments	Effective tillers (No. linear m^{-1})	Spike length (cm)	Filled grains spike^{-1} (No.)	Leaves plant^{-1} (No.)
M_1	77.00	15.53	47.17	9.69
M_2	79.39	15.76	47.25	8.70
SE	NS	NS	NS	NS
CV (%)	10.18	2.85	5.61	17.39

M_1 = 25 days old *Brassica* biomass M_2 = 35 days old *Brassica* biomass
NS = Not significant

4.2.5 Spike length

There was no significant variation of spike length observed for *Brassica* maturity (Appendix A.5) though the numerically maximum spike length (15.76 cm) was found with 35 days old *Brassica* biomass and the minimum (15.53 cm) was with 25 days old biomass (Table 5).

4.2.6 Number of filled grains spike^{-1}

Statistically insignificant variation was observed in number of filled grains per spike for *Brassica* maturity (Appendix A.6) though the maximum number of filled grains per spike (47.25) was recorded with 35 days old *Brassica* biomass and the minimum (47.17) was with 25 days old biomass (Table 5).

4.2.7 Number of leaves plant^{-1}

No significant variation was found in number of leaves per plant for *Brassica* maturity at 30 DAS (Appendix A.7) though the maximum number of leaves per plant (9.69) was observed with 25 days old *Brassica* biomass and the minimum (8.70) was with 35 days old biomass (Table 5).

4.2.8 Weight of 1000 grains

There was no significant variation observed for weight of thousand grains of wheat for *Brassica* maturity (Appendix A.8). Though the maximum weight of thousand grains (39.34 g) was found with 35 days old *Brassica* biomass and the minimum (38.44 g) was with 25 days old *Brassica* biomass (Table 6).

Table 6. Effect of *Brassica* maturity on weight of 1000 grains, grain yield, straw yield and harvest index of wheat

Treatments	Wt. of 1000 grains (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
M_1	38.44	2.38 b	3.18 b	42.96 a
M_2	39.34	2.68 a	3.89 a	41.71 b
SE	NS	0.0196	0.204	0.8825
CV (%)	4.75	4.71	12.54	4.67

M_1 = 25 days old *Brassica* biomass M_2 = 35 days old *Brassica* biomass
NS = Not significant

4.2.9 Grain yield

Significant variation of grain yield was recorded for variation of *Brassica* maturity (Appendix A.9). The higher grain yield (2.68 t ha^{-1}) was recorded with 35 days old *Brassica* biomass and the lower (2.38 t ha^{-1}) was found with 25 days old *Brassica* biomass (Table 6). The grain yield of wheat with 35 days old *Brassica* biomass was 11.19% higher compared to that of 25 days old *Brassica* biomass.

4.2.10 Straw yield

There was significant variation observed for straw yield of wheat for *Brassica* maturity (Appendix A.10). The higher straw yield (3.89 t ha^{-1}) was observed with 35 days old *Brassica* biomass and the lower (3.18 t ha^{-1}) was found with 25 days old biomass (Table 6).

4.2.11 Harvest index

Significant variation was observed for harvest index of wheat for *Brassica* maturity (Appendix A.11). The higher harvest index (42.96%) was found with 25 days old *Brassica* biomass and the lower (41.71) was found with 35 days old biomass (Table 6).

4.3 Effect of biomass amount

4.3.1 Weed population

Variation in weed population was observed significant for *Brassica* biomass concentration in both cases of 30 DAS and 60 DAS (Appendix A.1). At 30 DAS, the result showed that the highest weed population (165.70 m^{-2}) was recorded in the land with no *Brassica* biomass concentration, and the lowest weed population (99.17 m^{-2}) was with 1 kg biomass m^{-2} that was similar to the application of 0.5 kg biomass m^{-2} (Table 7). Similarly, at 60 DAS, the highest weed population (291.0 m^{-2}) was in no biomass treated plots, and the lowest population (176.0 m^{-2}) was with application of 1.0 kg biomass m^{-2} that was similar to the application of 0.5 kg biomass m^{-2}. Statistically similar results were also obtained by Ashrafi *et al.* (2007) who reported that Barley [*Hordeum vulgare* (L.) Koch.] contained water soluble allelochemicals and 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. Turk and Tawaha (2003) also reported that increasing the aqueous extract concentrations of separated *B. nigra* L., plant parts significantly inhibited *A. fatua* L. germination, seedling length and weight. Xuan and Tsuzuki (2001) also reported that the degree of inhibition of weed growth by alfalfa pellet became stronger as the application of concentration increased.

Table 7. Effect of biomass amount on weed population, weed dry weight and plant height of wheat

Treatments	Weed population (No. m^{-2})		Weed Dry wt. (g m^{-2})		Plant height (cm)	
	30 DAS	60DAS	30 DAS	60 DAS	30 DAS	At harvest
B_1	165.70 a	291.00 a	12.69 a	89.94 a	28.80 b	88.27
B_2	119.80 b	215.30 b	8.83 b	75.06 ab	31.24 ab	89.01
B_3	99.17 b	176.00 b	7.28 b	65.06 b	32.26 a	90.25
SE	14.125	15.209	1.128	5.7127	0.9705	NS
CV (%)	38.16	23.17	40.70	25.81	10.94	3.22

B_1 = 0 kg biomass m^{-2} B_2 = 0.5 kg biomass m^{-2} B_3 = 1.0 kg biomass m^{-2}
NS= Not significant

4.3.2 Weed dry weight

There was significant variation in dry weight of weed was recorded for *Brassica* biomass concentration in both cases of 30 DAS and 60 DAS (Appendix A. 2). The maximum dry weight of weed (12.69 g m^{-2}) was found with no biomass concentration, and the lowest (7.28 g m^{-2}) was with 1 kg biomass m^{-2} that was similar to the application of 0.5 kg biomass m^{-2} (Table 7). At 60 DAS, the highest dry weight of weed (89.94 g m^{-2}) was with no biomass concentration and the lowest (65.06 g m^{-2}) was with 1 kg biomass m^{-2} that was similar with the application of 0.5 kg biomass m^{-2}. Basotra *et al.* (2005) noted that the allelopathic effects of three important medicinal plant species (e.g., *Bergenia ciliata*, *Hedychium spicatum* and *Potentilla fulgens*) increased with increasing concentration of leachats from 2%, 5% to 10%. These results were also in agreement with the findings of Tawaha and Turk (2003) who observed that 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.

4.3.3 Plant height

Significant variation in plant height of wheat was observed for *Brassica* biomass concentration at 30 DAS and it was insignificant at harvest (Appendix A.3). At 30 DAS, the result showed that the highest plant height (32.26 cm) was from the land with 1.0 kg biomass concentration m^{-2} that was similar to the application of 0.5 kg biomass m^{-2}, and the lowest plant height (28.80 cm) was with no biomass concentration (Table 7). At harvest, the numerical maximum plant height (90.25 cm) was with 1.0 kg biomass m^{-2} and the minimum plant height (88.27 cm) was with no biomass concentration. These results were statistically dissimilar with the findings of Igbal and Cheema (2008) who noted that 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}).

4.3.4 Effective tillers linear m^{-1}

There was no significant variation for effective tillers linear m^{-1} for *Brassica* biomass concentration (Appendix A.4) though the maximum number of effective tillers linear m^{-1} (81.17) was recorded from the application of 0.5 kg biomass m^{-2} and the minimum (74.83) with the application of 1.0 kg biomass m^{-2} (Table 8). These results statistically dissimilar with the findings of Khan *et al.* (2008) who 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.

Table 8. Effect of biomass amount on effective tillers m^{-1}, spike length, filled grains $spike^{-1}$ and leaves $plant^{-1}$ of wheat

Treatments	Effective tillers (No. m^{-1})	Spike length (cm)	Filled grains $spike^{-1}$ (No.)	Leaves $plant^{-1}$ (No.)
B_1	78.58	15.59	45.76	8.74
B_2	81.17	15.80	48.01	8.81
B_3	74.83	15.55	47.88	10.03
SE	NS	NS	NS	NS
CV (%)	10.18	2.85	5.61	17.39

B_1 = 0 kg biomass m^{-2} B_2 = 0.5 kg biomass m^{-2} B_3 = 1.0 kg biomass m^{-2}
NS = Not significant

4.3.5 Spike length

Variation in spike length for *Brassica* biomass concentration was statistically insignificant (Appendix A.5) though the maximum spike length (15.80 cm) was found from the application of 0.5 kg biomass m^{-2} and the minimum (15.55 cm) with the application of 1.0 kg biomass m^{-2} (Table 8).

4.3.6 Filled grains $spike^{-1}$

There was no significant variation of number of filled grains $spike^{-1}$ observed for *Brassica* biomass concentration (Appendix A.6) though the maximum number of filled grains $spike^{-1}$ (48.01) was recorded with 0.5 kg biomass m^{-2} and the minimum (45.76) with the application of 1.0 kg biomass m^{-2} (Table 8).

4.3.7 Number of leaves $plant^{-1}$

No significant variation was recorded in number of leaves per plant for *Brassica* biomass concentration (Appendix A.7) at 30 DAS though the maximum number of leaves per plant (10.03) was found from the land with 1.0 kg biomass m^{-2} and the minimum (8.74) with no biomass concentration (Table 8).

4.3.8 Weight of 1000 grains

There was no significant variation of weight of thousand grains for *Brassica* biomass concentration (Appendix A.8) though the maximum weight of thousand grains (39.57 g) was recorded with the application of 1.0 kg biomass m^{-2} and the minimum (38.28 g) was found with no biomass application (Table-9). These results were similar with the findings of Mansoor *et al.* (2004) who stated that water extracts of sorghum, eucalyptus and acacia were significantly affected number of branches $plant^{-1}$, number of pods $plant^{-1}$, 1000 grain weight and grain yield of mungbean.

Table 9. Effect of biomass concentration in weight of 1000 grains, grain yield, straw yield and harvest index of wheat

Treatments	Wt. of 1000 grains (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
B_1	38.28	2.37 c	3.19 b	42.86
B_2	38.82	2.50 b	3.62 a	42.24
B_3	39.57	2.71 a	3.79 a	41.90
SE	NS	0.0344	0.128	NS
CV (%)	4.75	4.71	12.54	4.67

B_1 = 0 kg biomass m^{-2} B_2 = 0.5 kg biomass m^{-2} B_3 = 1.0 kg biomass m^{-2}
NS = Not significant

4.3.9 Grain yield

Statistically significant variation was recorded in grain yield of wheat for different *Brassica* biomass concentration (Appendix A.9). The highest grain yield (2.71 t ha^{-1}) was found with the application of 1 kg biomass m^{-2} and the lowest yield (2.37 t ha^{-1}) with no biomass concentration (Table 9). The grain yield of wheat was increased by 5.49% and 14.34% in 0.5kg biomass m^{-2} and 1.0 kg biomass m^{-2} respectively as compared to no biomass treated plots. Similar results also obtained by Naseem *et al*. (2009) who showed that inhibitory effects of sunflower plant water extract increased with increasing the water extract application frequency and increased the wheat yield significantly over control. These results were also in agreement with the findings of Cheema *et al.* (2003 b) who noted that concentrated sunflower water extract @ 12 L ha^{-1} sprayed at 30 and 40 days after sowing gave consistently better weed control and increased wheat yield by 5.5% over control.

4.3.10 Straw yield

There was significant variation of straw yield for different *Brassica* biomass concentration (Appendix A.10). The result showed that the highest straw yield (3.79 t ha^{-1}) was found with the application of 1.0 kg biomass m^{-2} that similar to 0.5 kg biomass m^{-2} (3.62 t ha^{-1}) and the lowest (3.19 t ha^{-1}) was with no biomass concentration (Table 10). Cheema *et al.* (1997) reported that the application of sorghum (*Sorghum bicolor*) and sunflower (*Helianthus annuus*) water extracts reduced weed biomass by 33-53% and increase in wheat yield by 7-14% .

4.3.11 Harvest index

Statistically no significant variation was observed in harvest index for different *Brassica* biomass concentration (Appendix A.11). The maximum harvest index (42.86%) was recorded with no biomass concentration and the minimum harvest index (41.90%) with the application of 1.0 kg biomass m^{-2} (Table 9).

4.4 Interaction effect of previous field status and *Brassica* maturity

4.4.1 Weed population

The interaction effect of field status and *Brassica* maturity showed statistically insignificant variation for weed population at 30 DAS and significant at 60 DAS (Appendix A.1). The numerical maximum weed population (174.00 m^{-2}) was found from fallow land with 35 days old *Brassica* and the minimum (98.67 m^{-2}) was recorded from the land with *Brassica* with 35 days old biomass at 30 DAS (Table 10). At 60 DAS, the highest weed population (308.40 m^{-2}) was found from fallow land with 35 days old *Brassica* that was similar to the same land with 25 days maturity of *Brassica* and the lowest population (162.70 m^{-2}) was recorded from the land of *Brassica* with 25 days old *Brassica* that showed similar result with the same land with 35 days old *Brassica*.

Table 10. Interaction effect of previous land status and *Brassica* maturity on weed population, weed dry weight and plant height of wheat

Treatments	Weed population (No. m^{-2})		Weed Dry wt. (g m^{-2})		Plant height (cm)	
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	At harvest
$C_1 \times M_1$	134.90	253.80 a	12.72 a	108.70 a	28.72 b	87.86
$C_1 \times M_2$	174.00	308.40a	13.85 a	106.80 a	29.20 ab	88.34
$C_2 \times M_1$	105.30	162.70 b	6.17 b	48.89 b	33.23 a	90.33
$C_2 \times M_2$	98.67	184.90b	5.67 b	42.32 b	31.91ab	90.17
SE	NS	14.274	0.8530	5.0694	1.0266	NS
CV (%)	38.16	23.17	40.70	25.81	10.938	3.22

C_1 = Previous fallow land
C_2 = Previous land with *Brassica*
M_1 = 25 days old *Brassica* biomass
M_2 = 35 days old *Brassica* biomass
NS = Not significant

4.4.2 Weed dry weight

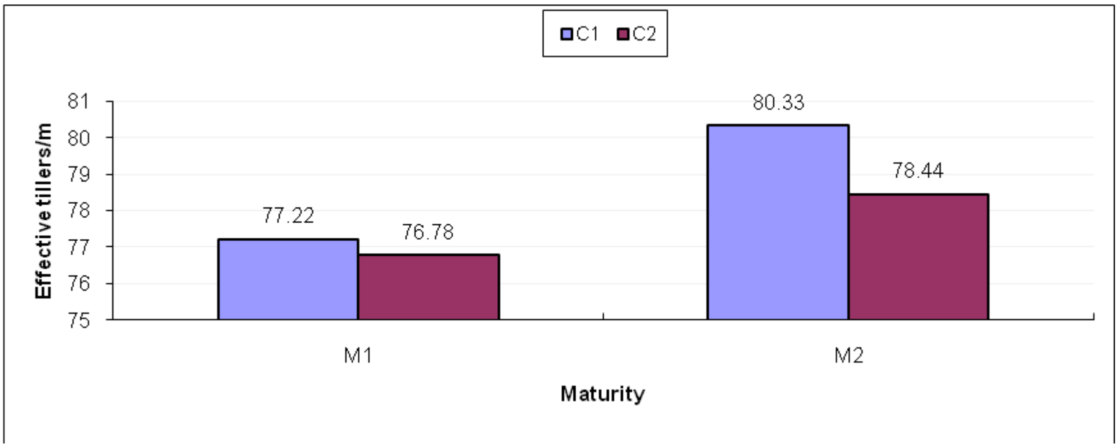
Statistically significant variation was observed for the interaction of field status and *Brassica* maturity on dry weight of weed for both cases of 30 DAS and 60 DAS (Appendix A.2). The highest dry weight of weed (13.85 g m^{-2}) was recorded from fallow land with 35 days old *Brassica* that showed similar result from the same land with 25 days old biomass at 30 DAS and the lowest (5.67 g m^{-2}) was found from the crop land with *Brassica* with 35 days old biomass that was similar to the same land with 25 days old biomass (Table 10). At 60 DAS, the highest dry weight of weed (108.70 g m^{-2}) was recorded from the land of *Brassica* with 25 days old *Brassica* that showed similar result with the same land with 35 days old *Brassica* and the lowest dry weight (42.32 g m^{-2}) from the land with *Brassica* with 35 days old *Brassica* that was similar to the same land with 25 days old *Brassica*.

4.4.3 Plant height

Significant variation was observed for the interaction of field status and *Brassica* maturity on plant height at 30 DAS and insignificant at harvest (Appendix A.3). At 30 DAS, the highest plant height (33.23 cm) was recorded from the land of *Brassica* with 25 days old *Brassica* and the lowest (28.72 cm) was found from the fallow land with 25 days old *Brassica* (Table 10). The maximum plant height (90.33 cm) was found from the land of *Brassica* with 25 days old *Brassica* and minimum (87.86 cm) from fallow land with 25 days old *Brassica* that showed insignificant result at harvest.

4.4.4 Effective tillers linear m^{-1}

The interaction effect of field status and *Brassica* maturity showed statistically insignificant variation for effective tillers linear m^{-1} (Appendix A.4). The result showed maximum number of effective tillers m^{-1} (80.33) from fallow land with 35 days old biomass and the minimum (76.78) was recorded from the land of *Brassica* with 25 days old biomass (Figure 3).

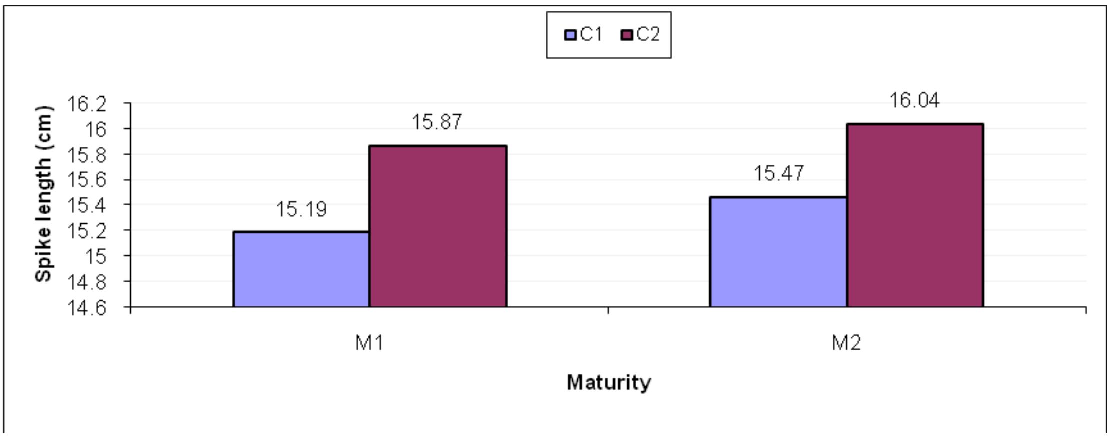


C_1 = Previous fallow land　　C_2 = Previous land with *Brassica*
M_1 = 25 days old *Brassica* biomass　　M_2 = 35 days old *Brassica* biomass

Figure 3: Interaction effect of previous field status and maturity of biomass on effective tillers of wheat

4.4.5 Spike length

Statistically significant variation was observed for the interaction of field status and *Brassica* maturity on spike length (Appendix A.5). The highest spike length (16.04 cm) was recorded from the land with *Brassica* and 35 days old biomass that showed similar (15.87 cm) result from the same land with 25 days old biomass and the lowest spike length (15.19 cm) was found from fallow land with 25 days old biomass that showed similar result (15.47 cm) from the same land with 35 days old biomass (Figure 4). The *Brassica* land with 35 and 25 days old biomass resulted 3.68% and 4.47% higher spike length as compared to no *Brassica* with same biomass maturity respectively.



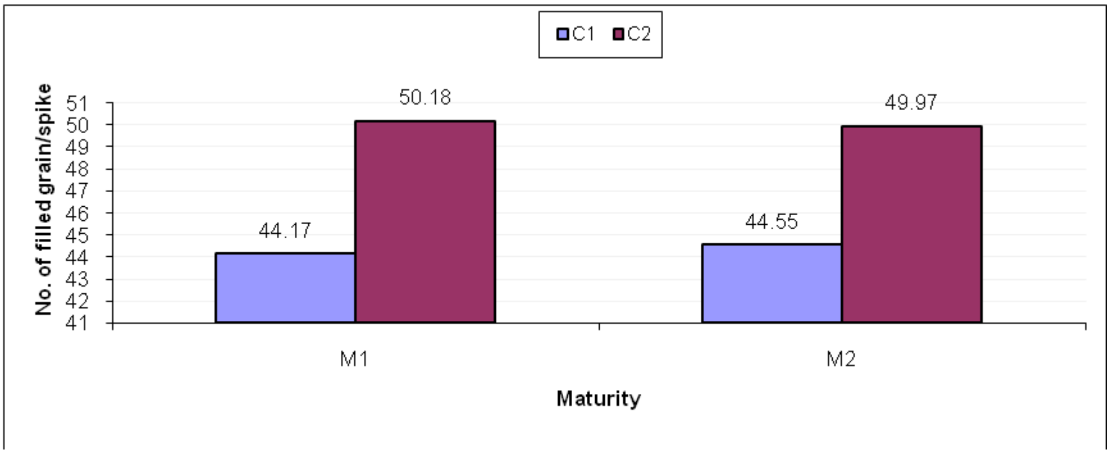
C_1 = Previous fallow land　　C_2 = Previous land with *Brassica*
M_1 = 25 days old *Brassica* biomass　　M_2 = 35 days old *Brassica* biomass

Figure 4. Interaction effect of field status and *Brassica* maturity on spike length of wheat. [SE = 0.1354]

4.4.6 Number of filled grains spike^{-1}

There was significant variation for the interaction of field status and *Brassica* maturity on number of filled grains spike^{-1} (Appendix A.6). The highest number of filled grains spike^{-1} (50.18) was recorded from the land of *Brassica* with 25 days old biomass that showed similar result from the same land with 35 days old biomass (Figure 5). The minimum number of filled grains spike^{-1}

(44.17) was recorded as from fallow land with 25 days old biomass that showed similar result from the same land with 35 days old biomass.

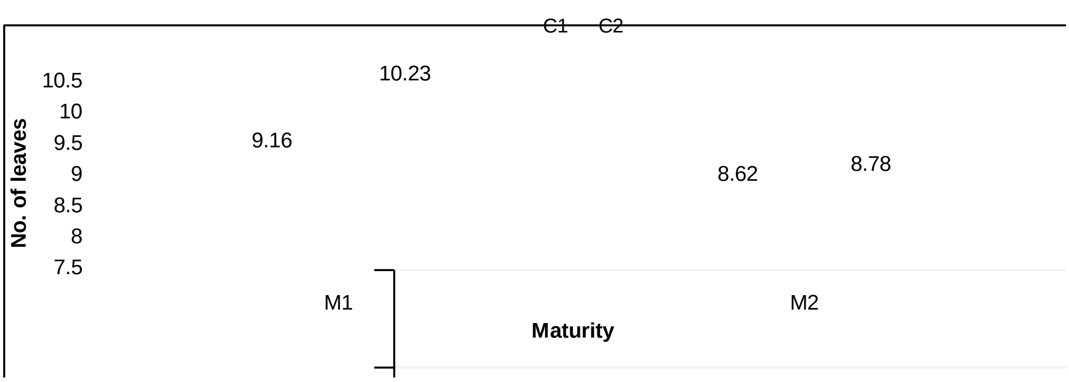


C_1 = Previous fallow land
M_1 = 25 days old *Brassica* biomass
C_2 = Previous land with *Brassica*
M_2 = 35 days old *Brassica* biomass

Figure 5. Interaction effect of field status and biomass maturity on number of filled grains per spike [SE=1.254]

4.4.7 Number of leaves plant^{-1}

The interaction effect of previous and *Brassica* maturity showed statistically insignificant variation for number of leaves per plant at 30 DAS (Appendix A.7) though the maximum number of leaves per plant (10.23) was found from the land of *Brassica* with 25 days old biomass and the lowest was 8.62 from fallow land with 35 days old biomass (Figure 6).



C_1 = Previous fallow land
M_1 = 25 days old *Brassica* biomass
C_2 = Previous land with *Brassica*
M_2 = 35 days old *Brassica* biomass

Figure 6. Interaction effect of field status and biomass maturity on number of leaves per plant

4.4.8 Weight of 1000 grains

Statistically significant variation was observed for the interaction of field status and *Brassica* maturity on weight of thousand grainss (Appendix A.8). The highest weight of thousand grains (41.23 g) was recorded from the land of *Brassica* with 35 days old biomass that showed similar (39.81 g) result with the same land with 25 days old biomass. The lowest weight (37.07 g) was found from fallow land with 25 days old biomass that was similar to the same land with 35 days old biomass as well as *Brassica* land with 25 days old biomass (Table 11).

Table 11. Interaction effect of field status and *Brassica* maturity on weight of 1000 grains, grain yield, straw yield and harvest index

Treatments	Wt. of 1000 grains (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
$C_1 \times M_1$	37.07 b	2.28 c	3.04	43.14
$C_1 \times M_2$	37.45 b	2.47 b	3.31	42.78
$C_2 \times M_1$	39.81 ab	2.66 a	3.79	41.60
$C_2 \times M_2$	41.23 a	2.70 a	3.99	41.81
SE	0.687	0.0278	NS	NS
CV (%)	4.75	4.71	12.54	4.67

C_1 = Previous fallow land
C_2 = Previous land with *Brassica*
M_1 = 25 days old *Brassica* biomass
M_2 = 35 days old *Brassica* biomass
NS = Not significant

4.4.9 Grain yield

Significant variation was found for the interaction of field status and *Brassica* maturity on grain yield (Appendix A.9). The highest grain yield (2.70 t ha^{-1}) was observed from the land with *Brassica* and 35 days old biomass that similar with the same land with 25 days old biomass (2.66 t ha^{-1}) and the lowest grain yield (2.28 t ha^{-1}) was recorded from fallow land with 25 days old biomass that similar to the same land with 35 days old biomass (Table 11).

4.4.10 Straw yield

The interaction effect of previous field status and *Brassica* maturity showed statistically insignificant variation for straw yield (Appendix A.10). Though the maximum straw yield (3.99 t ha^{-1}) was recorded from the land with *Brassica* with 35 days old biomass and the minimum yield (3.04 t ha^{-1}) was found from fallow land with 25 days old biomass (Table 11).

4.4.11 Harvest index

The interaction effect of field status and *Brassica* maturity showed statistically insignificant variation for harvest index (Appendix A.11) though the maximum harvest index (43.14%) was recorded from fallow land with 25 days old biomass and the minimum (41.60%) from the land with *Brassica* with 25 days old biomass (Table 11).

4.5 Interaction effect of field status and biomass concentration

4.5.1 Weed population

The combined effect of field status and *Brassica* biomass concentration revealed statistically significant variation for weed population on both cases of 30 DAS and 60 DAS (Appendix A.1). The highest weed population (203.30 m^{-2}) was recorded from fallow land with no biomass application and the lowest (80.33 m^{-2}) was recorded from the land with *Brassica* with application of 1.0 kg biomass m^{-2} that showed similar result with the all other kind of interactions except no *Brassica* field and no biomass at 30 DAS (Table 12). At 60 DAS, the highest weed population (337.30 m^{-2}) was observed from fallow land with no biomass application that showed similar result from the same land with 0.5 kg biomass m^{-2} and the lowest (134.70 m^{-2}) was recorded from the land with *Brassica* with the application of 0.5 kg biomass m^{-2} that showed similar result to the same field with 1.0 kg biomass m^{-2}. Statistically similar results were also obtained by Masiunas *et al.* (1995) who 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. Dissimilar results were also obtained by Barker and Bhowmik (2001) who reported that application of imported residues was more effective in weed control than the cover crop residues.

Table 12. Interaction effect of field status and biomass amount on weed population, weed dry weight and plant height of wheat

Treatments	Weed population (No. m^{-2})		Weed dry wt. (g m^{-2})		Plant height (cm)	
	30 DAS	60 DAS	30DAS	60 DAS	30 DAS	At harvest
$C_1 \times B_1$	203.30 a	337.30 a	18.56	124.10 a	26.37 b	86.78 b
$C_1 \times B_2$	142.00 b	296.00 ab	11.64	108.90 ab	29.99 ab	88.12 ab
$C_1 \times B_3$	118.00 b	210.0 c	9.64	90.39 b	30.53 ab	89.41 ab
$C_2 \times B_1$	128.00 b	244.70 bc	6.82	55.82 c	31.23 a	89.76 ab
$C_2 \times B_2$	97.67 b	134.70 d	6.01	41.26 c	32.50 a	89.91 ab
$C_2 \times B_3$	80.33 b	142.00d	4.92	39.74 c	33.98 a	91.09 a
SE	19.98	21.51	NS	8.079	1.372	1.172
CV (%)	38.16	23.17	40.70	25.81	10.938	3.22

C_1 = Previous fallow land C_2 = Previous land with *Brassica*
B_1 = 0 kg biomass m^{-2} B_2 = 0.5 kg biomass m^{-2} B_3 = 1.0 kg biomass m^{-2}
NS = Not significant

4.5.2 Weed dry weight

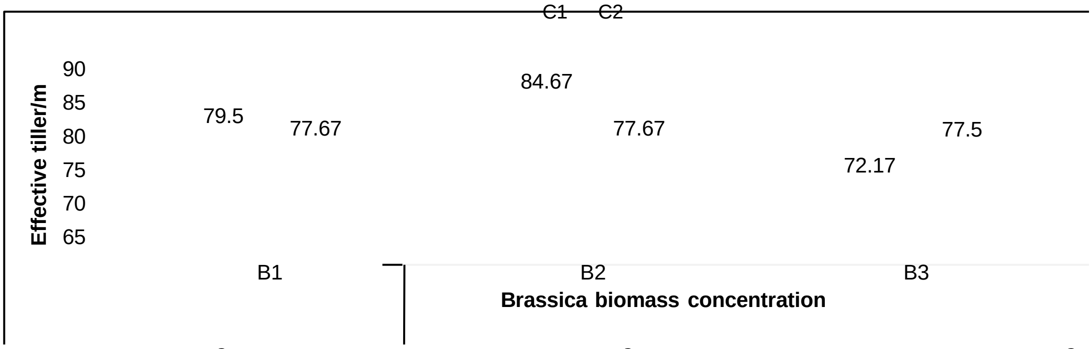
Statistically insignificant variation was observed for the interaction of field status and *Brassica* biomass concentration on dry weight of weed at 30 DAS and significant at 60 DAS (Appendix A.2). The maximum dry weight of weed (18.56 g m^{-2}) was observed from fallow land with no biomass application and the minimum (4.92 g m^{-2}) from the land with *Brassica* with 1 kg biomass m^{-2} at 30 DAS (Table 12). At 60 DAS, the highest weed dry weight (124.10 g m^{-2}) was recorded from fallow land with no biomass application that showed similar outcome from the same land with 0.5 kg biomass m^{-2} application and the lowest dry weight (39.74 g) was recorded from the land with *Brassica* with the application of 1.0 kg biomass m^{-2} that showed similar result from the same land with the application of 0.5 kg biomass m^{-2} and the same land with no biomass application. Statistically similar results also found by Masiunas *et al.* (1995) who 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 growth.

4.5.3 Plant height

The interaction effect of field status and *Brassica* biomass concentration on plant height of wheat was observed statistically significant on both cases at 30 DAS and at harvest (Appendix A.3). The highest plant height (33.98 cm) was observed from the land with *Brassica* and 1.0 kg biomass m^{-2} that showed similar outcome from the same land with all other biomass amount at 30 DAS (Table 12). At harvest, the highest plant height (91.09 cm) was recorded from the land with *Brassica* along with 1.0 kg biomass m^{-2} that showed similar result with other interactions except the interaction of fallow land with no biomass application that showed the lowest (86.78 cm) plant height.

4.5.4 Effective tillers linear m^{-1}

The combined effect of field status and *Brassica* biomass concentration showed significant variation for effective tillers linear m^{-1} (Appendix A.4). The highest effective tillers linear m^{-1} (84.67) was found from fallow land with the application of 0.5 kg biomass m^{-2} that showed similar result from rest of the other interactions except fallow land with 1.0 kg biomass m^{-2} (Figure 7).

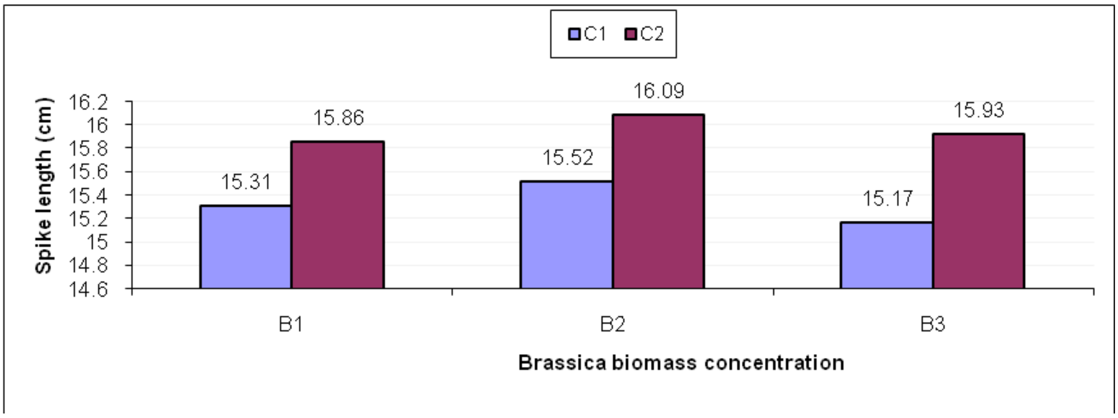


B_1 = 0 kg biomass m^{-2} B_2 = 0.5 kg biomass m^{-2} B_3 = 1.0 kg biomass m^{-2}
C_1 = Previous fallow land C_2 = Previous land with *Brassica*

Figure 7. Interaction effect of field status and biomass amount on effective tillers of wheat [SE=3.249]

4.5.5 Spike length

Statistically significant variation was observed for the interaction of field status and *Brassica* biomass on spike length of wheat (Appendix A.5). The highest spike length (16.09 cm) was recorded from the land with *Brassica* and with the application of 0.5 kg biomass m^{-2} that showed similar result from the same land with using 1.0 kg biomass m^{-2} (Figure 8). The lowest spike length (15.17 cm) was recorded from fallow land with the application of 1.0 kg biomass m^{-2}.

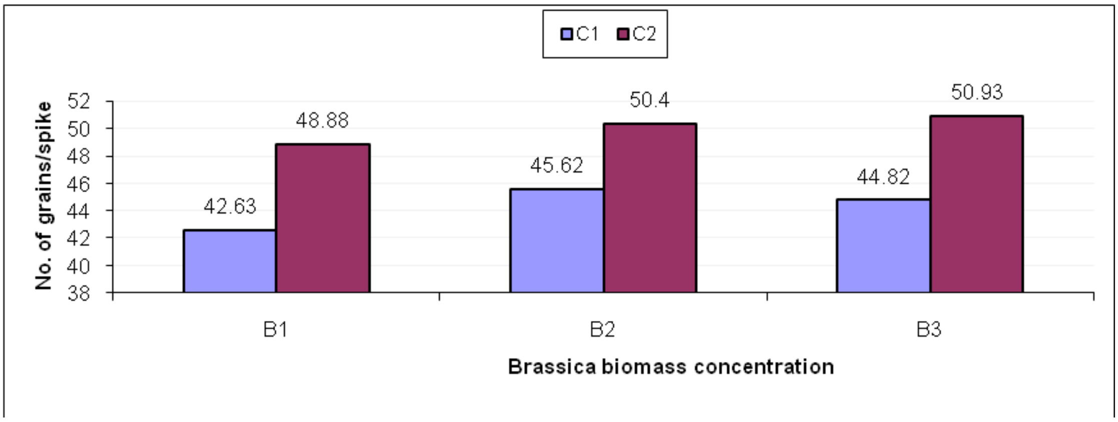


B_1 = 0 kg biomass m^{-2} B_2 = 0.5 kg biomass m^{-2} B_3 = 1.0 kg biomass m^{-2}
C_1 = Previous fallow land C_2 = Previous land with *Brassica*

Figure 8. Interaction effect of field status and biomass amount on spike length of wheat [SE=0.182]

4.5.6 Number of grains spike^{-1}

Significant variation was observed for the interaction of field status and *Brassica* biomass on number of grains per spike (Appendix A.6). The highest number of grains per spike (50.93) was observed from the land with *Brassica* and with the application of 1.0 kg biomass m^{-2} that showed similar result from the same land with other interactions (Figure 9). The lowest number of grain per spike (42.63) was found from fallow land with no biomass application that showed similar result from the same land with other interactions.

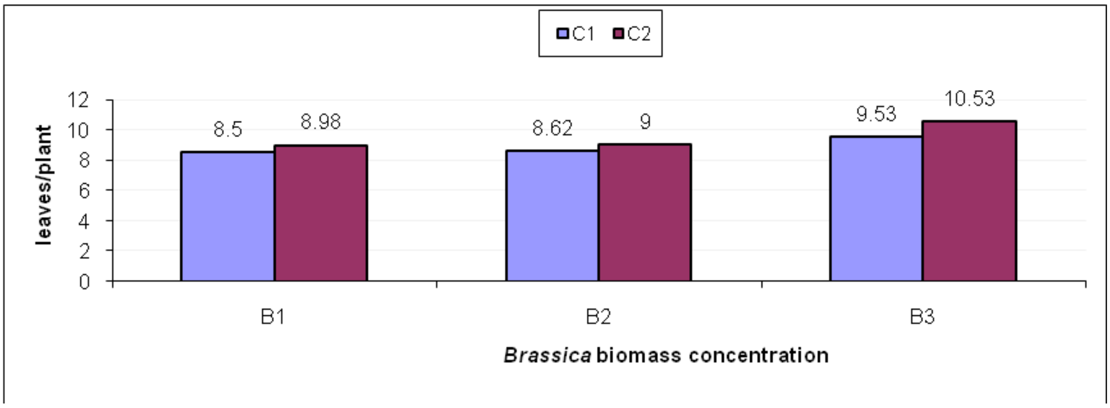


B_1 = 0 kg biomass m^{-2} B_2 = 0.5 kg biomass m^{-2} B_3 = 1.0 kg biomass m^{-2}
C_1 = Previous fallow land C_2 = Previous land with *Brassica*

Figure 9. Interaction effect of field status and biomass amount on number of Grains spike^{-1} of wheat [SE=1.081]

4.5.7 Number of leaves plant^{-1}

The interaction effect of field status and *Brassica* biomass amount showed statistically insignificant variation for number of leaves per plant (Appendix A.7) though the maximum number of leaves per plant (10.53) was recorded from the land with *Brassica* biomass and 1.0 kg biomass m^{-2} and the minimum (8.50) was recorded from fallow land with no biomass application (Figure 10).



B_1 = 0 kg biomass m^{-2} B_2 = 0.5 kg biomass m^{-2} B_3 = 1.0 kg biomass m^{-2}
C_1 = Previous fallow land C_2 = Previous land with *Brassica*

Figure 10. Interaction effect of field status and biomass amount on number of leaves per plant of wheat

4.5.8 Weight of 1000 grains

The interaction effect of field status and *Brassica* biomass amount showed statistically significant variation for weight of thousand grains (Appendix A.8). The highest weight of thousand grains (41.22 g) was recorded from the land with *Brassica* having 1.0 kg biomass m^{-2} that showed similar outcome from the same land with 0.5 kg biomass m^{-2} (Table 13). The lowest weight (36.68 g) was found from fallow land with 0.5 kg biomass m^{-2} that showed similar result from the same land with other interactions.

4.5.9 Grain yield

Statistically significant variation was observed for the interaction of field status and *Brassica* biomass amount on grain yield of wheat (Appendix A.9). The highest grain yield (2.83 t ha^{-1}) was found from the land with *Brassica* and application of 1.0 kg biomass m^{-2} and the lowest yield (2.19 t ha^{-1}) was observed from fallow land with no biomass application that showed similar result from the same land with 0.5 kg biomass m^{-2} (Table 13). Dissimilar results were obtained by Barker and Bhowmik (2001) who reported that application of imported residues was more effective in yield enhancement than the cover crop residues.

Table 13. Interaction effect of field status and biomass amount on weight of 1000 grains, grain yield, straw yield and harvest index of wheat

Treatments	Wt. of 1000 grains (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
$C_1 \times B_1$	37.19 bc	2.19 c	2.82 c	43.88
$C_1 \times B_2$	36.68 c	2.33 c	3.16 bc	42.63
$C_1 \times B_3$	37.92 bc	2.60 b	3.55 ab	42.38
$C_2 \times B_1$	39.37 ab	2.54 b	3.57 ab	41.83
$C_2 \times B_2$	40.96 a	2.68 b	4.08 a	41.85
$C_2 \times B_3$	41.22 a	2.83 a	4.03 a	41.43
SE	0.7538	0.0483	0.1807	NS
CV (%)	4.75	4.71	12.54	4.67

B_1 = 0 kg biomass m^{-2} B_2 = 0.5 kg biomass m^{-2} B_3 = 1.0 kg biomass m^{-2}

C_1 = Previous fallow land C_2 = Previous land with *Brassica* NS = not significant

4.5.10 Straw yield

The combined effect of field status and *Brassica* biomass concentration on straw yield of wheat showed significant variation (Appendix A.10). The highest straw yield (4.08 t ha^{-1}) was recorded from the land with *Brassica* and the application of 0.5 kg biomass m^{-2} that showed similar outcome from the same land with 1.0 kg biomass m^{-2} (Table 13). The lowest straw yield (2.82 t ha^{-1}) was noted from fallow land with no biomass application that showed similar outcome from same land with 0.5 kg biomass m^{-2}.

4.5.11 Harvest index

The combined effect of field status and *Brassica* biomass concentration showed statistically insignificant variation for harvest index (Appendix A.11) though the maximum harvest index (43.88%) was recorded from fallow land with no biomass application and the minimum (41.43%) was found from the land with *Brassica* and the application of 1.0 kg biomass m^{-2} (Table 13).

4.6 Interaction effect of *Brassica* maturity and biomass amount

4.6.1 Weed population

The interaction effect of *Brassica* maturity and *Brassica* biomass concentration showed statistically significant variation for weed population on both cases of 30 DAS and 60 DAS (Appendix A.1). The highest weed population (176.30 m^{-2}) was found from 35 days old *Brassica* plant with no biomass application on land that showed similar result from 25 days old *Brassica* with no biomass application and 35 days old *Brassica* with 0.5 kg biomass application; and the lowest population (95.67 m^{-2}) was found from 25 days old *Brassica* with the application of 1.0 kg biomass m^{-2} at 30 DAS (Table 14). At 60 DAS, the highest weed population (298.70 m^{-2}) was recorded from 35 days old *Brassica* with no biomass application that showed similar result from 25 days old *Brassica* with no biomass application on land and the lowest population (152.00 m^{-2}) was found from 25 days old *Brassica* with the application of 1.0 kg biomass m^{-2}.

Table 14. Interaction effect of *Brassica* maturity and biomass amount on weed population, weed dry weight and plant height of wheat

Treatments	Weed population (No. m^{-2})		Weed dry wt. (g m^{-2})		Plant height (cm)	
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	At harvest
$M_1 \times B_1$	155.00ab	283.30 a	12.41	92.81 a	28.92	88.37
$M_1 \times B_2$	109.70 b	189.30 bc	8.58	78.15 ab	32.15	88.64
$M_1 \times B_3$	95.670 b	152.00 c	7.34	65.43 b	31.87	90.28
$M_2 \times B_1$	176.30 a	298.70 a	12.98	87.07 ab	28.68	88.17
$M_2 \times B_2$	130.00 ab	241.30 ab	9.08	71.97 ab	30.34	89.38
$M_2 \times B_3$	102.70 b	200.00 bc	7.22	64.69 b	32.65	90.22
SE	19.98	21.51	NS	8.079	NS	NS
CV (%)	38.16	23.17	40.70	25.81	10.938	3.22

M_1 = 25 days old *Brassica* biomass M_2 = 35 days old *Brassica* biomass
B_1 = 0 kg biomass m^{-2} B_2 = 0.5 kg biomass m^{-2} B_3 = 1.0 kg biomass m^{-2}
NS = Not significant

4.6.2 Weed dry weight

Statistically insignificant variation was observed for the interaction of *Brassica* maturity and *Brassica* biomass amount on dry weight of weed at 30 DAS and significant at 60 DAS (Appendix A.2). The maximum dry weight of weed (12.98 g m^{-2}) was observed from 35 days old *Brassica* with no biomass application and the minimum dry weight (7.22 g m^{-2}) was found from 35 days old *Brassica* with the application of 1.0 kg biomass m^{-2} at 30 DAS (Table 14). At 60 DAS, the highest dry weight of weed (92.81 g m^{-2}) was recorded from 25 days old *Brassica* with no biomass application that showed similar result from 35 days old *Brassica* with no biomass application on land; same maturity with 0.5 kg biomass m^{-2} and 25 days old *Brassica* with 0.5 kg biomass m^{-2}.

4.6.3 Plant height

The interaction effect of *Brassica* maturity and *Brassica* biomass amount showed statistically insignificant variation for plant height at both cases of 30 DAS and at harvest (Appendix A.1). The numerically maximum plant height (32.65 cm) was recorded from 35 days old *Brassica* with the application of 1.0 kg biomass m^{-2} and the minimum (28.68 cm) was found from 35 days old

Brassica with no biomass application at 30 DAS (Table 14). At harvest, the maximum plant height (90.28 cm) was recorded from 25 days old *Brassica* with the application of 1.0 kg biomass m^{-2} and the minimum height (88.17cm) was found from 35 days old *Brassica* with no biomass application on land.

4.6.4 Effective tillers linear m^{-1}

The combined effect of *Brassica* maturity and *Brassica* biomass amount showed statistically insignificant variation for effective tillers linear m^{-1} (Appendix A.4) though the maximum effective tillers linear m^{-1} (85.00) was found from 35 days old biomass with the application of 0.5 kg biomass m^{-2} and the minimum (74.67) was found from 25 days old biomass with the application of 1.0 kg biomass m^{-2} (Table 15).

Table 15. Effect of *Brassica* maturity and biomass amount on effective tillers, spike length, filled grains spike^{-1} and leaves plant^{-1} of wheat

Treatments	Effective tillers (No. m^{-1})	Spike length (cm)	Filled grains spike^{-1} (No.)	Leaves plant^{-1} (No.)
$M_1 \times B_1$	79.00	15.38	45.87	9.65 ab
$M_1 \times B_2$	77.33	15.71	48.23	8.77 ab
$M_1 \times B_3$	74.67	15.51	47.42	10.67 a
$M_2 \times B_1$	78.17	15.80	45.65	7.83 b
$M_2 \times B_2$	85.00	15.89	47.78	8.86 ab
$M_2 \times B_3$	75.00	15.58	48.34	9.40 ab
SE	NS	NS	NS	0.6528
CV (%)	10.18	2.85	5.61	17.39

M_1 = 25 days old *Brassica* biomass M_2 = 35 days old *Brassica* biomass
B_1 = 0 kg biomass m^{-2} B_2 = 0.5 kg biomass m^{-2} B_3 = 1.0 kg biomass m^{-2}
NS = Not significant

4.6.5 Spike length

The interaction effect of *Brassica* maturity and *Brassica* biomass amount showed statistically insignificant variation for spike length (Appendix A.5) though the maximum spike length (15.89 cm) was recorded from 35 days old *Brassica* with the amount of 0.5 kg biomass m^{-2} and the minimum length (15.38 cm) was found from 25 days old *Brassica* with no biomass application on land (Table 15).

4.6.6 Number of filled grains spike^{-1}

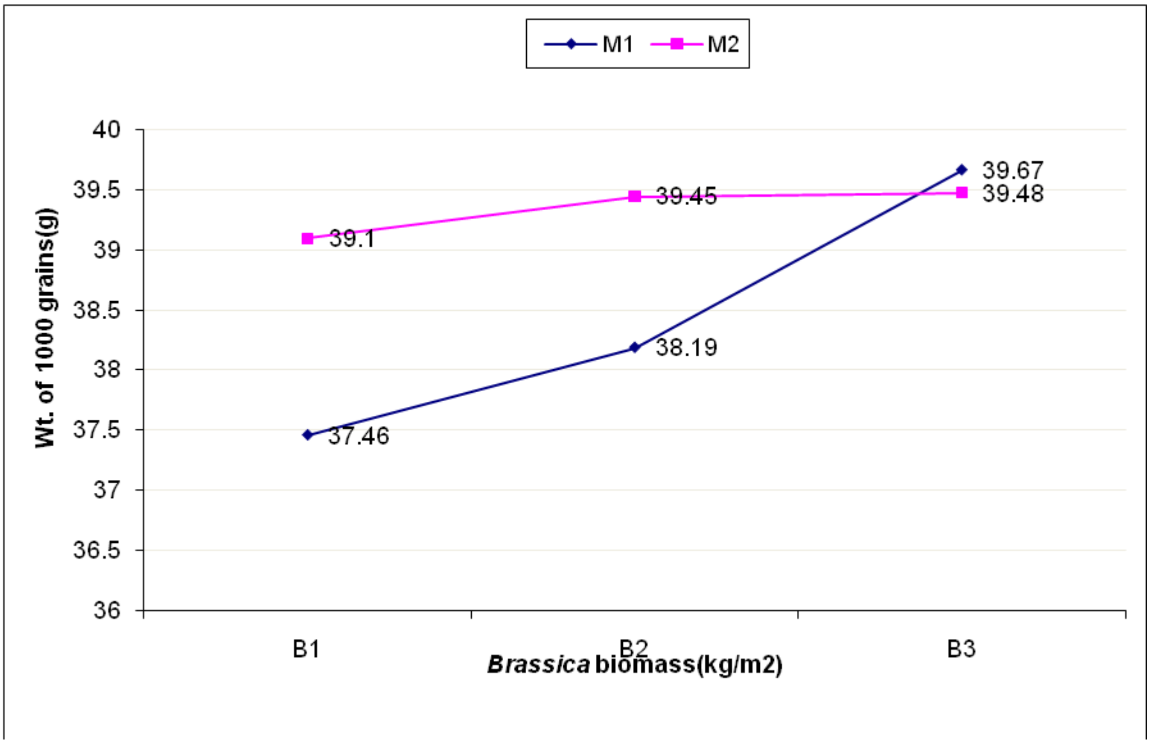
The combined effect of *Brassica* maturity and *Brassica* biomass amount showed statistically insignificant variation for number of grains per spike (Appendix A.6) though the maximum number of grains spike^{-1} (48.34) was observed from 35 days old *Brassica* with the application of 1.0 kg biomass m^{-2} and the minimum number of grains (45.65) was found from same maturity with no biomass application on land (Table 15).

4.6.7 Number of leaves plant^{-1}

Statistically significant variation was observed for the interaction of *Brassica* maturity and *Brassica* biomass amount on number of leaves per plant at 30 DAS (Appendix A.7). The highest number of leaves per plant (10.67) was recorded from 25 days old *Brassica* with the application of 1.0 kg biomass m^{-2} that showed similar result with all other interactions except the interaction of 35 days old *Brassica* with no biomass application on land that showed the lowest (7.83) number of leaves per plant (Table 15).

4.6.8 Weight of 1000 grains

The interaction effect of *Brassica* maturity and *Brassica* biomass amount showed statistically insignificant variation for weight of thousand grains (Appendix A.8) though the maximum weight of thousand grains (39.67 g) was recorded from 25 days old *Brassica* with the application of 1.0 kg biomass m^{-2} and the minimum weight (37.46 g) was recorded from the same maturity with no biomass application (Figure 11).

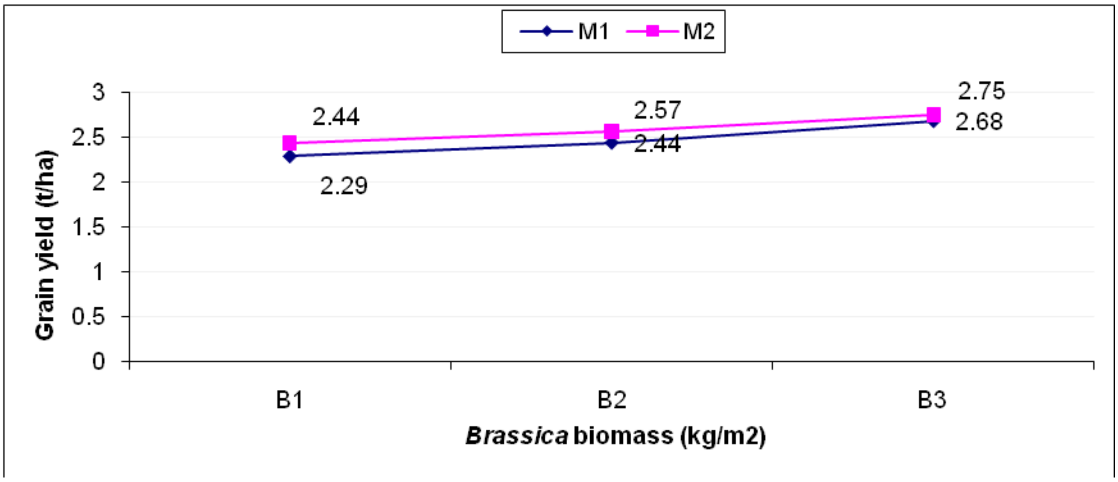


M_1 = 25 days old *Brassica* biomass M_2 = 35 days old *Brassica* biomass
B_1 = 0 kg biomass m^{-2} B_2 = 0.5 kg biomass m^{-2} B_3 = 1.0 kg biomass m^{-2}

Figure 11. Interaction effect of *Brassica* maturity and biomass amount on number of leaves per plant of wheat

4.6.9 Grain yield

Statistically significant variation was recorded for the interaction of *Brassica* maturity and *Brassica* biomass amount on grain yield of wheat (Appendix A.9). The highest grain yield (2.75 t ha^{-1}) was found from 35 days old *Brassica* with the application of 1.0 kg biomass m^{-2} that showed similar outcome from 25 days old *Brassica* with the application of same amount of biomass on land and the lowest yield (2.29 t ha^{-1}) from 25 days old *Brassica* with no biomass application on land (Figure 12).

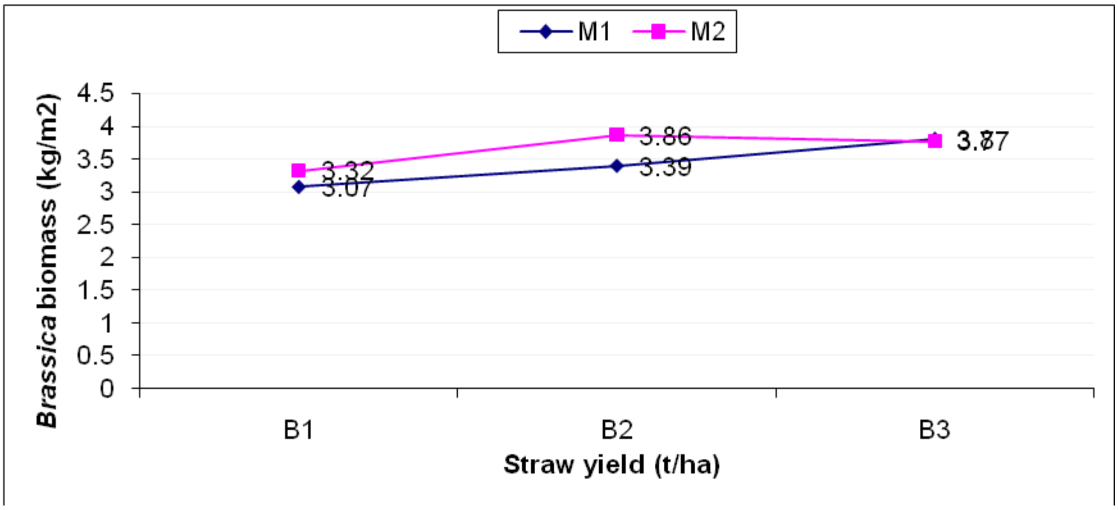


M_1 = 25 days old *Brassica* biomass M_2 = 35 days old *Brassica* biomass
B_1 = 0 kg biomass m^{-2} B_2 = 0.5 kg biomass m^{-2} B_3 = 1.0 kg biomass m^{-2}

Figure 12. Interaction effect of *Brassica* maturity and amount of biomass on grain yield of wheat [SE=0.0483]

4.6.10 Straw yield

The interaction of *Brassica* maturity and *Brassica* biomass amount on straw yield showed statistically significant response (Appendix A.10). The highest straw yield (3.86 t ha^{-1}) was observed from 35 days old *Brassica* with the application of 0.5 kg biomass m^{-2} on land that showed similar result from same maturity with 1.0 kg biomass m^{-2} and 25 days old *Brassica* with the application of 1.0 kg biomass m^{-2} (Figure 13). The lowest straw yield (3.07 t ha^{-1}) was recorded from 25 days old *Brassica* with no biomass application on land that showed similar result from same maturity with 0.5 kg biomass m^{-2} and 35 days old *Brassica* with no biomass application on land.

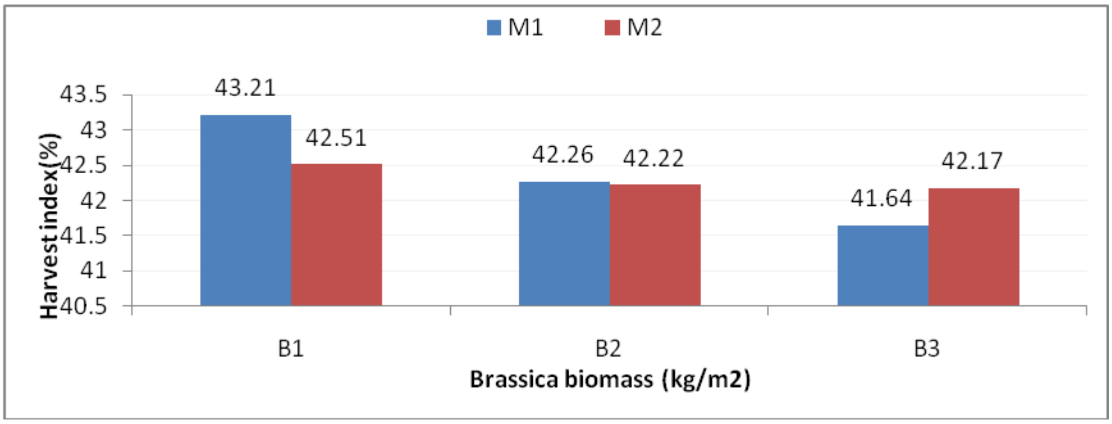


M_1 = 25 days old *Brassica* biomass M_2 = 35 days old *Brassica* biomass
B_1 = 0 kg biomass m^{-2} B_2 = 0.5 kg biomass m^{-2} B_3 = 1.0 kg biomass m^{-2}

Figure 13. Interaction effect *Brassica* maturity and biomass amount on straw yield of wheat [SE = 0.1807]

4.6.11 Harvest index

The combined effect of *Brassica* maturity and *Brassica* biomass amount showed statistically insignificant variation for harvest index (Appendix A.5) though the maximum harvest index (43.21%) was recorded from 25 days old *Brassica* with no biomass application on land and the minimum (41.64%) was found from same maturity with the application of 1.0 kg biomass m^{-2} on land (Figure 14).



M_1 = 25 days old *Brassica* biomass M_2 = 35 days old *Brassica* biomass
B_1 = 0 kg biomass m^{-2} B_2 = 0.5 kg biomass m^{-2} B_3 = 1.0 kg biomass m^{-2}

Figure 14. Interaction effect of *Brassica* maturity and biomass amount on harvest index of wheat

4.7 Interaction effect of field status, *Brassica* maturity and biomass amount

4.7.1 Weed population

Statistically significant variation was observed for the interaction of field status, *Brassica* maturity and *Brassica* biomass amount on weed population on both cases of 30 DAS and 60 DAS (Appendix A.1). The highest weed population (213.30 m^{-2}) was recorded from fallow land with 35 days old *Brassica* and no biomass application on land that showed similar outcome with the interaction of fallow land, 25 days old *Brassica* and no biomass application and the lowest population (73.33 m^{-2}) from the land of *Brassica* with 35 days old maturity and application of 1.0 kg biomass m^{-2} at 30 DAS (Table 16). At 60 DAS, the highest weed population (352.00 m^{-2}) was found from fallow land with 35 days old *Brassica* and no biomass application that showed similar result from same interaction and from same land with 25 days old *Brassica* and no biomass application on land and the lowest population (120.00 m^{-2}) was found from the land of *Brassica* with 25 days old *Brassica* and application of 0.5 kg biomass m^{-2} that showed similar result from same interaction with 1.0 kg biomass m^{-2}.

4.7.2 Weed dry weight

Statistically insignificant variation was observed for the interaction of field status, *Brassica* maturity and *Brassica* biomass amount on weed dry weight at 30 DAS but significant at 60 DAS (Appendix A.2). The maximum dry weight of weed (19.33 g m^{-2}) was recorded from fallow land with 35 days old *Brassica* and no biomass application and the minimum weight (4.81 g m^{-2}) was observed from the land with *Brassica* having 35 days old plants and the application of 1 kg biomass m^{-2} at 30 DAS (Table 16). At 60 DAS, the highest dry weight of weed (124.20 g m^{-2}) was found from fallow land with 35 days old *Brassica* and no biomass application that similar with all other interactions with fallow land

and the lowest weight (36.61 g m^{-2}) was found from the land of *Brassica* with 35 days old plants and application of 0.5 kg biomass m^{-2}.

Table 16. Interaction effect of field status, *Brassica* maturity and biomass amount on weed population, weed dry weight and plant height of wheat

Treatments	Weed population (No.m^{-2})		Weed dry wt. (g m^{-2})		Plant height (cm)	
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	At harvest
$C_1 \times M_1 \times B_1$	193.30 ab	322.70 ab	17.79	124.00 a	26.60 bc	87.00
$C_1 \times M_1 \times B_2$	107.30 def	258.70 abc	10.71	110.40 a	30.57 abc	87.12
$C_1 \times M_1 \times B_3$	104.00 def	180.00 cde	9.65	91.76 ab	29.00 abc	89.45
$C_1 \times M_2 \times B_1$	213.30 a	352.00 a	19.33	124.20 a	26.13 c	86.55
$C_1 \times M_2 \times B_2$	176.70 b	333.30 ab	12.58	107.30 a	29.41 abc	89.12
$C_1 \times M_2 \times B_3$	132.00 cd	240.00bcd	9.63	89.01 ab	32.07 abc	89.37
$C_2 \times M_1 \times B_1$	116.70 cde	244.00 bcd	7.03	61.65 bc	31.23 abc	89.73
$C_2 \times M_1 \times B_2$	112.0cdef	120.00 e	6.45	45.91 c	33.73 a	90.17
$C_2 \times M_1 \times B_3$	87.33 efg	124.00 e	5.03	39.11 c	34.73 a	91.10
$C_2 \times M_2 \times B_1$	139.30 c	245.30 bcd	6.62	49.99 c	31.23 abc	89.78
$C_2 \times M_2 \times B_2$	83.33 fg	149.30 de	5.58	36.61 c	31.27 abc	89.65
$C_2 \times M_2 \times B_3$	73.33 g	160.00 cde	4.81	40.37 c	33.23 ab	91.08
SE	8.934	30.42	NS	11.43	1.941	NS
CV (%)	38.16	23.17	40.70	25.81	10.938	3.22

C_1 = Previous fallow land C_2 = Previous land with *Brassica*
M_1 = 25 days old *Brassica* biomass, M_2 = 35 days old *Brassica* biomass
B_1 = 0 kg biomass m^{-2} B_2 = 0.5 kg biomass m^{-2} B_3 = 1.0 kg biomass m^{-2}
NS = Not significant

4.7.3 Plant height

The interaction effect of field status, *Brassica* maturity and *Brassica* biomass amount showed statistically significant variation at 30 DAS and insignificant at 60 DAS for plant height of wheat (Appendix A.3). The highest plant height (34.73 cm) was found from the land of *Brassica* with 25 days old biomass and application of 1.0 kg biomass m^{-2} that was similar with the same land with same maturity and application of 0.5 kg biomass m^{-2} the lowest height (26.13 cm) was found from fallow land with 35 days old maturity and no biomass application on land at 30 DAS (Table 16). At harvest, the numerical maximum plant height (90.17 cm) was recorded from the land of *Brassica* with 25 days old biomass and application of 0.5 kg biomass m^{-2} and the minimum (87.00 cm) from fallow land with 25 days old *Brassica* and no biomass application on land.

4.7.4 Effective tillers linear m^{-1}

Statistically significant variation was observed for the interaction of field status, *Brassica* maturity and *Brassica* biomass amount on effective tillers linear m^{-1} (Appendix A.4). The highest effective tillers linear m^{-1} (88.33) was recorded from fallow land with 35 days old *Brassica* and application of 0.5 kg biomass m^{-2} that similar with the other interactions, except the interaction of fallow crop land, 25 days old *Brassica* and application of 1.0 kg biomass m^{-2} that showed lowest (71.33) tillers linear m^{-1} (Table-17).

4.7.5 Spike length

The interaction effect of field status, *Brassica* maturity and *Brassica* biomass amount showed statistically significant variation for spike length (Appendix A.5). The longest spike length (16.17 cm) was observed from the land of *Brassica* with 35 days old biomass and application of 0.5 kg biomass m^{-2} that showed similar result with same crop land with 35 days old *Brassica* and no biomass application, and same crop land with 25 days old *Brassica* and application of 0.5 kg biomass m^{-2} (Table 17). The shortest spike length (15.05 cm) was found from fallow land with 25 days old *Brassica* and no biomass application that showed similar outcome with same land with 25 days old *Brassica* and application of 1.0 kg biomass m^{-2}

Table 17. Interaction effect of field status, *Brassica* maturity and biomass amount on effective tillers, spike length, filled grains spike^{-1} and leaves plant^{-1} of wheat

Treatments	Effective tillers (No. linear m^{-1})	Spike length (cm)	No. of filled Grains spike^{-1} (No.)	No. of leaves plant^{-1}(No.)
$C_1 \times M_1 \times B_1$	79.33 ab	15.05 d	43.10 e	8.33 ab
$C_1 \times M_1 \times B_2$	81.00 ab	15.42 abcd	45.77 bcde	8.93 ab
$C_1 \times M_1 \times B_3$	71.33 b	15.12 cd	43.63 de	10.20 a
$C_1 \times M_2 \times B_1$	79.67 ab	15.57 abcd	42.17 e	8.67 ab
$C_1 \times M_2 \times B_2$	88.33 a	15.62 abcd	45.47 cde	8.31 ab
$C_1 \times M_2 \times B_3$	73.00 ab	15.22 bcd	46.01 bcde	8.87 ab
$C_2 \times M_1 \times B_1$	78.67 ab	15.70 abcd	48.63 abcd	10.97 a
$C_2 \times M_1 \times B_2$	73.67 ab	16.01 ab	50.70 ab	8.60 ab
$C_2 \times M_1 \times B_3$	78.00 ab	15.90 abcd	51.20 a	11.13 a
$C_2 \times M_2 \times B_1$	76.67 ab	16.02 ab	49.13 abc	7.00 b
$C_2 \times M_2 \times B_2$	81.67 ab	16.17 a	50.10 abc	9.40 ab
$C_2 \times M_2 \times B_3$	77.00 ab	15.95 abc	50.67 ab	9.93 ab
SE	4.595	0.2576	1.529	0.9232
CV (%)	10.18	2.85	5.61	17.39

C_1 = Previous fallow land; C_2 = Previous land with *Brassica*
M_1 = 25 days old *Brassica* biomass, M_2 = 35 days old *Brassica* biomass
B_1 = 0 kg biomass m^{-2}; B_2 = 0.5 kg biomass m^{-2}; B_3 = 1.0 kg biomass m^{-2}
NS = Not significant

4.7.6 Number of filled grains spike^{-1}

Significant variation was observed for the interaction of field status, *Brassica* maturity and *Brassica* biomass amount on number of filled grains per spike (Appendix A.6). The highest number of filled grains per spike (51.20) was recorded from the land of *Brassica* with 25 days old *Brassica* and application of 1.0 kg biomass m^{-2} on land that showed similar result with same land with same maturity and application of 0.5 kg biomass m^{-2}, and same land with 35 days old biomass and application of 1.0 kg biomass m^{-2} (Table 17). The lowest filled grains per spike (42.17) was noted from fallow land with 35 days old *Brassica* and 0.5 kg biomass m^{-2} application on land that showed similar result with same land with 25 days old *Brassica* and no biomass application, and same land with 25 days old biomass and application of 1.0 kg biomass m^{-2}.

4.7.7 Number of leaves plant^{-1}

The interaction effect of field status, *Brassica* maturity and *Brassica* biomass amount showed statistically significant variation for number of leaves per plant at 30 DAS (Appendix A.7). The highest number of leaves per plant (11.13) was recorded from the land of *Brassica* with 25 days old biomass and application of 1.0 kg biomass m^{-2} on land that similar with other interactions, except from the interaction of land of *Brassica* with 35 days old biomass and no biomass application on land that showed lowest (7.00) number of leaves plant^{-1} (Table 17).

4.7.8 Weight of 1000 grains

Statistically significant variation was observed for the interaction of field status, *Brassica* maturity and *Brassica* biomass amount on weight of thousand grains of wheat (Appendix A.8). The highest weight of thousand grains (41.84 g) was observed from the land of *Brassica* with 35 days old *Brassica* and 0.5 kg biomass m^{-2} that showed similar result with same land with same maturity and application of 1.0 kg biomass m^{-2}, and same land with 25 days old *Brassica* and application of 1.0 kg biomass m^{-2} (Table 18). The lowest thousand grains weight (36.29 g) was recorded from fallow land with 25 days old *Brassica* and application of 0.5 kg biomass m^{-2} that similar with same land with same maturity and no biomass application, and same land with 35 days old *Brassica* and application of 0.5 kg biomass m^{-2}.

4.7.9 Grain yield

The interaction effect of field status, *Brassica* maturity and *Brassica* biomass amount showed statistically significant variation for grain yield of wheat (Appendix A.9). The highest grain yield (2.86 t ha^{-1}) was recorded from the land of *Brassica* with 35 days old *Brassica* and application of 1.0 kg biomass m^{-2} that similar with same land with same maturity and application of 0.5 kg biomass m^{-2}, and same land with 25 days old biomass and the application of 1.0 kg biomass m^{-2} (Table 18). The lowest yield (2.06 t ha^{-1}) was observed from fallow land with 25 days old *Brassica* and no biomass application that similar with same land with same maturity and application of 0.5 kg biomass m^{-2}.

Table 18: Interaction effect of field status, *Brassica* maturity and biomass amount on weight of 1000 grains, grain yield, straw yield and harvest index of wheat

Treatments	Wt. of 1000 grains (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
$C_1 \times M_1 \times B_1$	36.31 d	2.06 f	2.58 d	44.45
$C_1 \times M_1 \times B_2$	36.29 d	2.22 ef	3.05 cd	42.49
$C_1 \times M_1 \times B_3$	38.61 abcd	2.56 bcd	3.50 bc	42.47
$C_1 \times M_2 \times B_1$	38.07 bcd	2.33 de	3.05 cd	43.31
$C_1 \times M_2 \times B_2$	37.06 cd	2.44 cd	3.28 bcd	42.77
$C_1 \times M_2 \times B_3$	37.23 bcd	2.64 abc	3.61 abc	42.28
$C_2 \times M_1 \times B_1$	38.61 abcd	2.53 bcd	3.55 bc	41.96
$C_2 \times M_1 \times B_2$	40.09 abc	2.66 abc	3.72 abc	42.03
$C_2 \times M_1 \times B_3$	40.72 ab	2.80 a	4.11 ab	40.80
$C_2 \times M_2 \times B_1$	40.13 abc	2.55 bcd	3.58 bc	41.71
$C_2 \times M_2 \times B_2$	41.84 a	2.69 ab	4.44 a	41.67
$C_2 \times M_2 \times B_3$	41.73 a	2.86 a	3.94 ab	42.06
SE	1.066	0.06831	0.2556	NS
CV (%)	4.75	4.71	12.54	4.67

C_1 = Previous fallow land C_2 = Previous land with *Brassica*
M_1 = 25 days old *Brassica* biomass, M_2 = 35 days old *Brassica* biomass
B_1 = 0 kg biomass m^{-2} B_2 = 0.5 kg biomass m^{-2} B_3 = 1.0 kg biomass m^{-2}
NS = Not significant

4.7.10 Straw yield

Statistically significant variation was observed for the interaction of field status, *Brassica* maturity and *Brassica* biomass concentration on straw yield (Appendix A.10). The highest straw yield (4.44 t ha^{-1}) was observed from the land of *Brassica* with 35 days old *Brassica* and the application of 0.5 kg biomass m^{-2} that similar with same land with same maturity and application of 1.0 kg biomass m^{-2}, and same land with 25 days old *Brassica* and application of 1.0 kg biomass m^{-2} (Table 18). The lowest straw yield (2.58 t ha^{-1}) was found from fallow land with 25 days old *Brassica* and no biomass application that similar with same land with same maturity and application of 0.5 kg biomass m^{-2} and same land with 35 days old *Brassica* and no biomass application.

4.7.11 Harvest index

The interaction effect of field status, *Brassica* maturity and *Brassica* biomass amount showed statistically insignificant variation for harvest index (Appendix A.10). The maximum harvest index (44.45%) was recorded from fallow land with 25 days old *Brassica* and no biomass application and the minimum harvest index (40.80%) was found from the land of *Brassica* with 25 days old *Brassica* and application of 1 kg biomass m^{-2} (Table 18).

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, 2008 to March, 2009 to find out the allelopahtic effect of *Brassica* biomass on weed control and yield of wheat. The treatment of the experiment consisted of 2 levels of crop field viz. fallow land (C_1) and field with *Brassica* (C_2); 2 levels of *Brassica* maturity viz. 25 days old *Brassica* (M_1) and 35 days old *Brassica* (M_2); and 3 levels of *Brassica* biomass amount viz. 0 kg biomass m^{-2} (B_1), 0.5 kg biomass m^{-2} (B_2) and 1.0 kg biomass m^{-2} (B_3). The experiment was laid out in a spilt split-plot design following the principles of randomization with three replications. The sowing date of wheat was on December 07, 2008. The unit plot size was 3m x 3m = 09 m^2.

Observations were made on wheat as weed population, dry weight of weed, plant height, number of effective tillers linear m^{-1}, spike length, number of filled grains spike^{-1}, number of leaves plant^{-1}, weight of 1000 grains, grain yield, straw 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 after sowing and 60 days after sowing. Ten plants were randomly selected per plot for taking plant height, spike length, number of filled grains spike^{-1} and number of leaves plant^{-1}. Effective tillers were counted per linear meter from each plot. Thousand grains weight (g) was measured from sample seed. An area of 6.0 m^2 from each plot was harvested for grain yield and straw yield. Harvest index was calculated from grain yield and straw yield.

The findings showed that field status influenced weight of 1000 grains, grain yield, straw yield and harvest index. The highest weight of thousand grains (40.52 g), grain yield (2.68 t ha^{-1}) and straw yield (3.89 t ha^{-1}) was found from field with *Brassica* biomass and the highest harvest index (42.96%) was found from fallow land.

Maturity of *Brassica* biomass influenced weed population, dry weight of weed, grain yield, straw yield and harvest index. The lowest weed population (208.22 m^{-2}) at 60 DAS was found from 25 days old *Brassica*. The highest grain yield (2.68 t ha^{-1}) and straw yield (3.89 t ha^{-1}) were recorded from 35 days old *Brassica* biomass and lowest dry weight of weed at 30 DAS (45.61g m^{-2}) from 35 days old biomass. *Brassica* biomass amount influenced weed population, dry weight of weed, plant height, grain yield (t ha^{-1}) and straw yield (t ha^{-1}). The lowest weed population at 30 DAS (99.17 m^{-2}) and at 60 DAS (176.00 m^{-2}) and dry weight of weed at 30 DAS (7.28 g m^{-2}) and at 60 DAS (65.06 g m^{-2}) was found with 1.0 kg m^{-2} biomass application in the field. The highest plant height at 30 DAS (32.26 cm), grain yield (2.71 t ha^{-1}) and straw yield (3.79 t ha^{-1}) were found with the application of 1 kg biomass m^{-2}.

The interaction effect of field status and *Brassica* maturity was found significant in cases of weed population, dry weight of weed, plant height, spike length, number of filled grains $spike^{-1}$, weight of 1000 grains and grain yield (t ha^{-1}). The lowest weed population at 60 DAS (162.70 m^{-2}) was found in *Brassica* field with 25 days old biomass and the lowest weed dry weight 5.67 g m^{-2} and 42.32 g m^{-2} at 30 and 60 DAS respectively was found from *Brassica* land with 35 days old biomass. The highest plant height (33.23 cm) and number of filled grains $spike^{-1}$ (50.18) was found in *Brassica* field with 25 days old biomass. The highest weight of thousand grains (41.23 g) and grain yield (2.70 t ha^{-1}) was found in the interaction of *Brassica* field and 35 days old biomass.

The interaction effect of field status and *Brassica* biomass amount showed significant result on weed population (80.33 m^{-2} and 142.00 m^{-2} at 30 and 60 DAS respectively), dry weight of weed (39.74 g m^{-2}), plant height (33.98 cm at 30 DAS and 91.09 cm at 60 DAS) with *Brassica* field and 1.0 kg m^{-2} biomass application. The highest number of effective tillers linear m^{-1} (84.67) was found in fallow land with 0.5 kg m^{-2} biomass application. The highest spike length

(16.09 cm) was in *Brassica* field with 0.5 kg m^{-2} biomass application. The highest number of filled grains $spike^{-1}$ (50.93), number of leaves $plant^{-1}$ (10.53), weight of 1000 grains (41.22 g), grain yield (2.83 t ha^{-1}) and straw yield (4.03 t ha^{-1}) was found from field with *Brassica* and application of 1.0 kg biomass m^{-2}.

The interaction effect of *Brassica* maturity and *Brassica* biomass amount showed significant result in cases of weed population, dry weight of weed, grain yield and straw yield. The lowest weed population at 30 DAS (95.67 m^{-2}) and at 60 DAS (152.00 m^{-2}) was found in 25 days old *Brassica* with 1.0 kg biomass m^{-2}. The lowest weed dry weight (64.69 g m^{-2}) at 60 DAS was found in 35 days old *Brassica* and 1.0 kg biomass m^{-2}. Interaction of 35 days old biomass and 1.0 kg biomass amount m^{-2} showed the highest grain yield (2.75 t ha^{-1}) but the highest straw yield (3.86 t ha^{-1}) was found in 35 days old *Brassica* with 0.5 kg biomass m^{-2} application.

The interaction effect of field status, *Brassica* maturity and concentration of *Brassica* biomass showed significant result in all cases of yield contributing characters and yield of wheat except harvest index. The lowest weed population (73.33 m^{-2}) at 30 DAS was found in *Brassica* field with 35 days old biomass with 1.0 kg m^{-2}. The lowest weed dry weight at 60 DAS (36.61 g m^{-2}) was found in *Brassica* field with 35 days old *Brassica* applied @ 0.5 kg m^{-2}. The highest grain yield was found in *Brassica* field with 25 to 35 days old *Brassica* @ 1.0 kg m^{-2}.

Spike length, number of filled grains $spike^{-1}$, number of leaves $plant^{-1}$, weight of thousand grains, grain yield and straw yield were revealed higher by the interaction of land with *Brassica*, both 25 and 35 days old biomass and application of 1.0 kg biomass m^{-2}.

In short, fallow land 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. On the other hand, land with *Brassica*, 35 days old *Brassica* biomass and amount of 1.0 kg *Brassica* biomass m^{-2} (in some cases 0.5 kg biomass m^{-2}) and their interaction encouraged increasing yield of wheat and yield contributing characters.

However, to reach 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-A: Analysis of variance for yield and other yield attributes

1. Weed population

1.1 Weed population at 30 DAS

Sources of Variation	Degrees of Freedom	Sum of Square	Mean Square	F Value
Replication	2	9849.556	4924.778	0.3922
Crop (C)	1	24753.778	24753.778	1.9711
Error (a)	2	25116.222	12558.111	
Maturity (M)	1	2368.444	2368.444	0.3274
C×M	1	4715.111	4715.111	0.6517
Error (b)	4	28939.111	7234.778	
Biomass (B)	2	27800.222	13900.111	5.8052
C ×B	2	2424.222	1212.111	0.5062
M×B	2	384.222	192.111	0.0802
C×M×B	2	3816.222	1908.111	0.7969
Error (c)	16	38311.111	2394.444	

1.2 Weed population at 60 DAS

Sources of Variation	Degrees of Freedom	Sum of Square	Mean Square	F Value
Replication	2	21158.222	10579.111	0.8674
Crop (C)	1	103684.000	103684.000	8.5015
Error (a)	2	24392.000	12196.000	
Maturity (M)	1	13301.778	13301.778	7.2538
C×M	1	2368.444	2368.444	1.2916
Error (b)	4	7335.111	1833.778	
Biomass (B)	2	81990.222	40995.111	14.7677
C ×B	2	14034.667	7017.333	2.5279
M×B	2	2427.556	1213.778	0.4372
C×M×B	2	192.889	96.444	0.0347
Error (c)	16	44416.000	2776.000	

2. Weed dry weight

2.1 Weed dry weight at 30 DAS

Sources of Variation	Degrees of Freedom	Sum of Square	Mean Square	F Value
Replication	2	80.451	40.225	0.6067
Crop (C)	1	487.747	487.747	7.3563
Error (a)	2	132.607	66.303	
Maturity (M)	1	0.906	0.906	0.1383
C×M	1	5.945	5.945	0.9080
Error (b)	4	26.191	6.548	
Biomass (B)	2	186.373	93.187	6.1031
C ×B	2	87.309	43.655	2.8591
M×B	2	0.867	0.433	0.0284
C×M×B	2	2.563	1.282	0.0839
Error (c)	16	244.301	15.269	

2.2 Weed dry weight at 60DAS

Sources of Variation	Degrees of Freedom	Sum of Square	Mean Square	F Value
Replication	2	4515.310	2257.655	4.6453
Crop (C)	1	34774.791	34774.791	71.5524
Error (a)	2	972.010	486.005	
Maturity (M)	1	160.107	160.107	0.6922
C×M	1	49.562	49.562	0.2143
Error (b)	4	925.145	231.286	
Biomass (B)	2	3760.915	1880.457	4.8017
C ×B	2	597.133	298.566	0.7624
M×B	2	54.726	27.363	0.0699
C×M×B	2	97.210	48.605	0.1241
Error (c)	16	6265.957	391.622	

3. Plant height

3.1 Plant height at 30 DAS

Sources of Variation	Degrees of Freedom	Sum of Square	Mean Square	F Value
Replication	2	6.487	3.244	0.2097
Crop (C)	1	117.253	117.253	7.5813
Error (a)	2	30.932	15.466	
Maturity (M)	1	1.592	1.592	0.1678
C×M	1	7.317	7.317	0.7715
Error (b)	4	37.938	9.485	
Biomass (B)	2	75.850	37.925	3.3555
C ×B	2	8.433	4.217	0.3731
M×B	2	10.259	5.129	0.4538
C×M×B	2	9.774	4.887	0.4324
Error (c)	16	180.837	11.302	

3.2 Plant height at harvest

Sources of Variation	Degrees of Freedom	Sum of Square	Mean Square	F Value
Replication	2	33.861	16.930	5.7881
Crop (C)	1	41.710	41.710	14.2595
Error (a)	2	5.850	2.925	
Maturity (M)	1	0.242	0.242	0.0329
C×M	1	0.951	0.951	0.1292
Error (b)	4	29.431	7.358	
Biomass (B)	2	24.085	12.043	1.4601
C ×B	2	3.122	1.561	0.1893
M×B	2	1.536	0.768	0.0931
C×M×B	2	3.990	1.995	0.2419
Error (c)	16	131.960	8.247	

4. Effective tiller

Sources of Variation	Degrees of Freedom	Sum of Square	Mean Square	F Value
Replication	2	220.389	110.194	3.4169
Crop (C)	1	12.250	12.250	0.3798
Error (a)	2	64.500	32.250	
Maturity (M)	1	51.361	51.361	1.4984
C×M	1	4.694	4.694	0.1370
Error (b)	4	137.111	34.278	
Biomass (B)	2	243.389	121.694	1.9215
C ×B	2	230.167	115.083	1.8171
M×B	2	127.389	63.694	1.0057
C×M×B	2	5.056	2.528	0.0399
Error (c)	16	1013.333	63.333	

5. Spike length

Sources of Variation	Degrees of Freedom	Sum of Square	Mean Square	F Value
Replication	2	0.594	0.297	0.9053
Crop (C)	1	3.516	3.516	10.7214
Error (a)	2	0.656	0.328	
Maturity (M)	1	0.456	0.456	2.7624
C×M	1	0.022	0.022	0.1334
Error (b)	4	0.660	0.165	
Biomass (B)	2	0.456	0.228	1.1464
C ×B	2	0.081	0.040	0.2033
M×B	2	0.188	0.094	0.4720
C×M×B	2	0.013	0.007	0.0330
Error (c)	16	3.180	0.199	

6. Filled grains/spike

Sources of Variation	Degrees of Freedom	Sum of Square	Mean Square	F Value
Replication	2	36.420	18.210	0.5527
Crop (C)	1	293.951	293.951	8.9222
Error (a)	2	65.892	32.946	
Maturity (M)	1	0.065	0.065	0.0046
C×M	1	0.789	0.789	0.0558
Error (b)	4	56.609	14.152	
Biomass (B)	2	38.285	19.142	2.7288
C ×B	2	3.948	1.974	0.2814
M×B	2	3.218	1.609	0.2294
C×M×B	2	7.157	3.579	0.5101
Error (c)	16	112.240	7.015	

7. Leaf number

Sources of Variation	Degrees of Freedom	Sum of Square	Mean Square	F Value
Replication	2	6.245	3.123	1.4126
Crop (C)	1	3.460	3.460	1.5651
Error (a)	2	4.421	2.210	
Maturity (M)	1	8.960	8.960	3.1183
C×M	1	1.886	1.886	0.6564
Error (b)	4	11.494	2.873	
Biomass (B)	2	12.663	6.332	2.4759
C ×B	2	0.667	0.333	0.1304
M×B	2	5.778	2.889	1.1298
C×M×B	2	13.507	6.754	2.6409
Error (c)	16	40.916	2.557	

8. Weight of 1000 grains

Sources of Variation	Degrees of Freedom	Sum of Square	Mean Square	F Value
Replication	2	4.883	2.441	2.2034
Crop (C)	1	95.485	95.485	86.1833
Error (a)	2	2.216	1.108	
Maturity (M)	1	7.335	7.335	1.7331
C×M	1	2.470	2.470	0.5836
Error (b)	4	16.929	4.232	
Biomass (B)	2	10.063	5.032	1.4760
C ×B	2	6.656	3.328	0.9762
M×B	2	5.588	2.794	0.8196
C×M×B	2	2.598	1.299	0.3810
Error (c)	16	54.545	3.409	

9. Grain yield

Sources of Variation	Degrees of Freedom	Sum of Square	Mean Square	F Value
Replication	2	0.111	0.056	277.8648
Crop (C)	1	0.852	0.852	4257.5254
Error (a)	2	0.000	0.000	
Maturity (M)	1	0.121	0.121	17.5206
C×M	1	0.055	0.055	7.9780
Error (b)	4	0.028	0.007	
Biomass (B)	2	0.734	0.367	25.8644
C ×B	2	0.024	0.012	0.8373
M×B	2	0.011	0.005	0.3735
C×M×B	2	0.020	0.010	0.7165
Error (c)	16	0.227	0.014	

10. Straw yield

Sources of Variation	Degrees of Freedom	Sum of Square	Mean Square	F Value
Replication	2	3.383	1.691	15.7239
Crop (C)	1	4.587	4.587	42.6398
Error (a)	2	0.215	0.108	
Maturity (M)	1	0.488	0.488	0.6511
C×M	1	0.012	0.012	0.0166
Error (b)	4	2.996	0.749	
Biomass (B)	2	2.277	1.138	5.7935
C ×B	2	0.303	0.151	0.7709
M×B	2	0.384	0.192	0.9784
C×M×B	2	0.377	0.188	0.9583
Error (c)	16	3.144	0.196	

11. Harvest index

Sources of Variation	Degrees of Freedom	Sum of Square	Mean Square	F Value
Replication	2	69.978	34.989	107.1120
Crop (C)	1	14.213	14.213	43.5101
Error (a)	2	0.653	0.327	
Maturity (M)	1	0.043	0.043	0.0030
C×M	1	0.734	0.734	0.0523
Error (b)	4	56.078	14.019	
Biomass (B)	2	5.622	2.811	0.7188
C ×B	2	2.839	1.420	0.3630
M×B	2	2.267	1.134	0.2899
C×M×B	2	1.736	0.868	0.2220
Error (c)	16	62.577	3.911	

PLATES

Plate 1. Field view of *Brassica*

Plate 2. Harvested *Brassica*

Plate 3. Field view of experiment at early stage

Plate 4. Field view of experiment at maturity stage

Plate 5. Field view of experiment after harvest

Plate 6. Wheat plant having different levels of *Brassica*

Plate 7. Variation of weed status