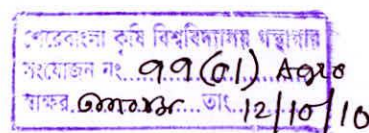


**ALLELOPATHIC EFFECT OF *Brassica* BIOMASS TO CONTROL
WEEDS AND YIELD OF WHEAT**

BY

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A Thesis

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CERTIFICATE

This is to certify that the thesis entitled “**Allelopathic Effect of Brassica Biomass to Control Weeds and Yield of Wheat**” submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in AGRONOMY**, embodies the result of a piece of bonafide research work carried out by **Md. Monzur Morshed**, Registration number: **03-01183** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has duly been acknowledged.

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ALLELOPATHIC EFFECT OF *Brassica* BIOMASS TO CONTROL WEEDS AND YIELD OF WHEAT

ABSTRACT

The experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2007 to February 2008 to study the allelopathic effect of *Brassica* biomass to control weeds and yield of wheat. The experiment consisted of two factors of which Factor A: 3 kinds of *Brassica* species viz. S_1 : *Brassica campestris*, S_2 : *Brassica juncea* and S_3 : *Brassica napus* and Factor B: Incorporation methods of *Brassica* biomass (5 levels) like: B_0 : Control (no biomass application); B_1 : Spreading above the ground; B_2 : Mixed with soil; B_3 : Spreading in line and B_4 : 50% spreading + 50% mixed with soil. At 30 days after sowing (DAS), the maximum numbers of weeds (25.53 m^{-2}) were found in the plot treated with *Brassica juncea* which was 44.81% higher than *Brassica campestris*. At 50 DAS, *Brassica juncea* also showed the highest weed population (20.20 m^{-2}). However, *Brassica campestris* resulted with the best effect on weed control showing the least number of weed population (14.07 m^{-2}). At 30 DAS, the lowest weed population (15.33 m^{-2}) was seen by B_3 while the highest (26.89 m^{-2}) was found in the B_2 . At 50 DAS, the highest (20.89 m^{-2}) weed population was found by B_2 whereas, B_4 showed the lowest (13.11 m^{-2}) population. S_1B_2 showed the lowest density of weeds (8.67 m^{-2}) at 50 DAS which was significantly lower than S_2B_0 (37.33 m^{-2}) and S_3B_2 (40.00 m^{-2}) at 30 and 50 DAS respectively. Among the *Brassica* species, S_2 produced the highest grain yield (3.52 t ha^{-1}) while the lowest (3.32 t ha^{-1}) was obtained from S_3 . The highest grain yield (3.54 t ha^{-1}) was recorded from B_0 while the lowest (3.32 t ha^{-1}) was recorded from B_2 . The S_2B_1 had the highest grain yield (3.83 t ha^{-1}) whereas the lowest (3.06 t ha^{-1}) was recorded from S_3B_1 . It is appeared from the above results that *Brassica campestris* and B_4 incorporation method was mostly effective in controlling weed. But yield was not affected by both species and incorporation methods.



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CHAPTER 1

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops of the World followed by rice. It is a staple food crop for about one billion people in as many as 43 countries and provides about 20% of the 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 is the second most important staple food crop and 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 but 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 infestation is a major one. Weed competition in wheat crop has been reported to decrease yield by 42 and 56% during 1994-1995 and 1995-1996, respectively (El-Hamid *et al.*, 1998). It was also reported that the yield of wheat was reduced by 20-30% due to weed infestation (Khan *et al.*, 1975 and Turk and Tawaha, 2002). Peterson (1965) said that the yield loss could be 150% due to weed infestation. Different weed control methods increased grain and straw yields, effective tillers plant⁻¹, panicle length and filled grains panicle⁻¹ of wheat compared to weedy check (Tariful *et al.*, 1998).

In Bangladesh, manual weeding (hand weeding) is generally practiced to control weeds in wheat field but the scarcity of labourers as well as increased labour wages enforce urgently to find out alternate ways of weed control. Managing croplands according to nature's principles will reduce weed problems. Allelopathy offers potential for selective biological weed management through the production and release of allelochemicals from leaves, flowers, seeds, stems, and roots of living or decomposing plant materials (Weston, 1996). Allelopathic inhibition typically results from the combined action of a group of allelochemicals which, collectively, interfere with severe physiological processes (Blum, 1996). Barnes and Putnam (1986) has been reported reduce weed germination and growth by shading, lowering soil temperatures, moderating diurnal temperature fluctuation, and acting as a physical barrier to reduce weeds.

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. Besides this practice increases the soil organic matter content for improving soil physical properties. Rapeseed and mustard contain high amounts of glucosinolates is one of the most useful allelopathic cover crop that reduced total weed biomass in soybean by 40 – 49% (Krishnan *et al.*, 1998). 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). Yenish and Worsham (1993) also reported the highest weed control by rye application in the field for the commencing crop.

Boydston and Hang (1995) reported that all members of the *Brassica* family contain mustard oils. When mustard plants are incorporated with the soils that inhibit plant growth and seed germination. Sullivan (2003) reported that crop residues when left on the soil surface could be expected to reduce weed emergence by 75 to 90% compared to the control condition. If *Brassica* spp. plant tissues are incorporated into the soil, it is possible to control weeds in the following crop in the

form the mulch materials (Brown and Morra, 1995; Boydston and Hang, 1995; Al-Khatib *et al.*, 1997). This might be a chance to reduce the use of herbicides and could be an additional tool to control herbicide-resistant weeds.

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

- To identify different weed species grown in different allelopathic treatment.
- To study the effect of different *Brassica* spp. on weed control in wheat field.
- To compare effectivity of different incorporation methods of *Brassica* biomass to control weeds in the succeeding wheat crop.
- To find out the best combination of Brassica incorporation methods for optimum growth and yield of wheat.



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 or 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 different crop species

Bellostas *et al.* (2007) reported that glucosinolates were amino acid derived allelochemicals present in all plants of the order Capparales. Species within the Brassicaceae are found to differ in their glucosinolate profile and glucosinolate concentrations. The glucosinolate profile of corresponding ripe seeds was also determined. The determined glucosinolate profiles are 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 ant 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* may be a source of natural weedicide against *Ageratina adenophora* which will help to control invasive plants.

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

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

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

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.

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 of Florida beggarweed (*Desmodium tortuosum* DC.), compared to the gravel-mulched and no-mulch controls.

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 leachates from 2%, 5% to 10%. The susceptible crops were *Amaranthus caudatus* and *Phaseolus mungoo* whose germination, radicle and plumule growth were reduced significantly under aqueous extracts of all three medicinal species.

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

Shiraishi *et al.* (2005) experimented with shamrock oxalis (*Oxalis articulata* Savigny), Bowie's woodsorrel (*Oxalis bowiei* Lindl.), trefoil (*Oxalis brasiliensis* Lodd. ex Knowl. et West.), lucky clover (*Oxalis deppei* Lodd. ex Sweet) and *Oxalis*

hirta L. The leachates from *O. articulata*, *O. bowiei*, *O. deppei* and *O. hirta* and the exudates from *O. deppei* caused > 84% inhibition of the radicle elongation of lettuce seedlings, but no effect was observed on the seed germination of lettuce. *O. deppei* significantly reduced the weed population in July. A significant relationship was observed between the weed population and the percentage ground coverage of *Oxalis* spp. In contrast to the weed population, a significant relationship was observed between the weed above-ground biomass and the allelopathic activity of exudates from *Oxalis* spp.

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

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⁻¹, Number of pods plant⁻¹, 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.

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.

Severino and Christoffoleti (2004) designed a field experiment to determine the effect of the green manure species *Crotalaria juncea*, *Arachis pintoii* 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) tested 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.

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.



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.

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 are more effective and economical to control the weeds of many crops. In mature sorghum plants nine water soluble allelochemicals have been identified which are phytotoxic to the growth of certain weeds.

Petersen *et al.* (2001) evaluated the allelopathic potential of isothiocyanates (ITC) released by turnip–rape mulch [*Brassica rapa* (Rapifera Group)–*Brassica napus* L.]. They found that Isothiocyanates were strong suppressants of germination on tested species spiny sowthistle [*Sonchus asper* (L.) Hill], scentless mayweed

(*Matricaria inodora* L.), smooth pigweed (*Amaranthus hybridus* L.), barnyardgrass [*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 illinoensis* 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 may also increase rye's allelopathic activity, and hence its weed suppression ability in the field.

Chandra Babu and Kandasamy (1997) evaluated allelopathic potential of *Eucalyptus globulus* Labill. (gum tree) 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 is a possibility to harness the allelochemicals of eucalyptus leaves as herbicides for the management of these perennial weeds.

Smolinska (1996) reported that *Brassica* tissues are 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.

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%.

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

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

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, heat, oat, grass pea, and mustard are 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.

Rye cover crop residue was proved to be effective at reducing light transmittance (quality and quantity) and soil temperature which in turn can reduce or delay germination and emergence of certain weed species (Teasdale and Mohler, 1993).

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) have demonstrated allelopathic effects, the ability of a plant to exude them as a defensive response has 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.

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.

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.

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.

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.

Putnam and DeFrank (1983) showed reductions in germination and growth of several problem agronomic weeds including barnyardgrass (*Echinochloa crusgalli* L.), common lambsquarters (*Chenopodium album* L.), common ragweed (*Ambrosia artemisiifolia* L.), green foxtail [*Setaria viridis* (L.) Beauv.], and redroot pigweed (*Amaranthus retroflexus* L.)

2.2 Effect on incorporation methods

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, 578, 61, 686 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.

Dhima *et al.* (2006) conducted a study to measure the effect of two barley (*Hordeum vulgare* L.) and six triticale (*xTriticosecale*) 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.

Maiksteniene and Arlauskiene (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.

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.

Xuan *et al.* (2005) 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 juncuncum*, *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 may become effective tools in reducing plant pathogens and weeds. Numerous growth inhibitors (alkaloids, phenolics, fatty acids, lactones, and flavonoids) identified from these allelopathic plants are responsible for their allelopathic properties.

Xuan *et al.* (2005) 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.

Gallandt and Haramoto (2004) reported allelopathic potential has 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.

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

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.

Turk and Tawaha (2003) reported that black mustard (*Brassica nigra* L.) contains 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.) are 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.

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.

Daimon and Kotoura (2000) stated that *Crotalaria spectabilis* incorporation significantly increased wheat dry weight and nitrogen uptake. However, values for HD plant incorporation were significantly lower than those for LD and MD plant incorporation at 80 and 120 days after seeding. A reduction of the dry weight and

total root length of wheat grown with aqueous extracts of HD plants was found in a growth pouch experiment.

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.

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

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 may permit selective management of these weeds in wheat. Flixweed, stinkweed, and downy brome are major winter annual weeds in winter wheat and usually require late fall or early spring herbicide treatments in no-tillage systems. Therefore, residues of canola, lentil, oat and barley have 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.

Boydstone 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 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.

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.

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.

Rose *et al.* (1984) experimented on 280 soybean cultivars and found 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.

So, from the above review of literature, it is clear that the effect of allelopathy is present in different species and *Brassica* had a noticeable effect. Different incorporation methods also showed the effect of allelopathy with effectiveness in controlling weeds.



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 entitled “Weed control and yield of wheat as affected by incorporation methods of *Brassica* biomass” carried out during rabi season (October to February) of 2007-'08, at the central farm of Sher-e-Bangla Agricultural University, Dhaka-1207. The experimental field was located at 90°22' E longitude and 23°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 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). The weather data during the study period at the experimental site is presented in Appendix I.

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. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done at Soil Resource and Development Institute (SRDI), Dhaka. The physicochemical properties of the soil found from the analysis are presented in Appendix II.

3.4 Crop/planting material

3.4.1 Description of *Brassica* cultivars

Three cultivars of *Brassica* were chosen in our study. The salient features of the cultivars are given below:

3.4.1.1 BARI Sarisha-11

Brown coloured and bold seeded BARI Sarisha 11 is drought and salinity tolerant and suitable for late cultivation. It is a tall plant and siliquae are appressed in the inflorescence. The variety is resistant to *Orobanche*. It takes 110–120 days to mature and yield potentiality ranges from 2.00–2.40 t ha⁻¹. It is a variety under *Brassica juncea* group.

3.4.1.2 BARI Sarisha-13

Light brown coloured and bold seeded BARI Sarisha 13 is drought and salinity tolerant. It is a tall plant and siliquae are appressed in the inflorescence. The variety is resistant to *Orobanche*. It takes 115–130 days to mature and yield potentiality ranges from 2.10–2.55 t ha⁻¹. It is a variety under *Brassica napus* group.

3.4.1.3 BARI Sarisha-15

Dark brown coloured and bold seeded BARI Sarisha 15 is drought tolerant sarisha. It is a tall plant and siliquae are appressed in the inflorescence. The variety is resistant to *Orobanche*. It takes 105–120 days to mature and yield potentiality ranges from 2.15–2.5 t ha⁻¹. It is a variety under *Brassica campestris* group.

3.4.2 Description of wheat cultivar Shatabdi

Shatabdi (BARI Gom-21), a modern wheat variety released by BARI in 2000 was selected as a study material in our experimentation. It is a semi-dwarf (95 – 100cm) cultivar with good tillering capability. It produces generally 5-6 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. Lower glume beak is long and the lower glume shoulder shape is elevated. The total life duration ranges from 105-110 days and the vegetative phase (66-75 days) is longer than any other variety so far released in our country. The grains are white and large with 1000-grain ranges from

46-48g. The variety is resistant to leaf rust and highly tolerant to *Bipolaris* leaf blight. The variety has good level of tolerance to heat stress and is best suited both under optimum and late planting for rice-wheat cropping system. The variety yields 3600-5000 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 including saline areas with salinity level around 6 mmhos.

3.5 Experimental treatments

There were two factors of treatments in the experiment. It was *Brassica* species as sources of biomass and their incorporative methods. They are shown as below:

Factor A: *Brassica* Species (3 levels) in the main plot which are –

- i. S_1 : *Brassica campestris*
- ii. S_2 : *Brassica juncea*
- iii. S_3 : *Brassica napus*

Factor B: Methods of biomass application (5 levels) in sub plots which are –

- i. B_0 : Control (no biomass application)
- ii. B_1 : Spreading above the ground
- iii. B_2 : Mixed with soil
- iv. B_3 : Spreading in line
- v. B_4 : 50% spreading + 50% mixed with soil

3.6 Layout of the experiment

3.6.1 Layout of *Brassica* spp.

The experimental plot was divided into three blocks. One of the three *Brassica* species was sown randomly in each block. The block was 29 m $\times$ 7 m in size with 1m distance between blocks. The layout of the experiment is shown in Figure 1.

3.6.2 Layout of main experiment

The experiment was laid out in split-plot design with three replications. Each block was divided into three main plots in which three *Brassica* variety were applied at random. Each main plot was further divided into 5 unit plots or sub-plots and different dozes of *Brassica* biomass were applied there at random. So, the total number of unit plots in the entire experimental plot was $3 \times 3 \times 5 = 45$. Size of each



unit plot was $5\text{m} \times 2\text{m} = 10\text{m}^2$. The distance maintained between two sub-plots was 0.5m and between blocks 1m (Figure 2).

3.7 Collection and preparation of initial soil sample

The initial soil samples were collected before land preparation from a 0-15 cm soil depth. The samples were collected by means of an auger from different location covering the whole experimental plot and mixed thoroughly to make a composite sample. After collection of soil samples, the plant roots, leaves etc. were picked up and removed. Then the sample was air-dried and sieved through a 10-mesh sieve and stored in a clean plastic container for physical and chemical analysis.

3.8 Details of the field operations

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

3.8.1 Land preparation and laying out of experimental unit

The experimental field was first opened on 25th October, 2007 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 3rd November 2007 according to design immediately after final land preparation. After harvesting the *Brassica* sp. at their 30 days after sowing, the land was again prepared as before. The final ploughing and land preparation was done on December 4, 2007 and layout was done as per experimental design. Individual plots were cleaned and finally leveled with the help of wooden plank.

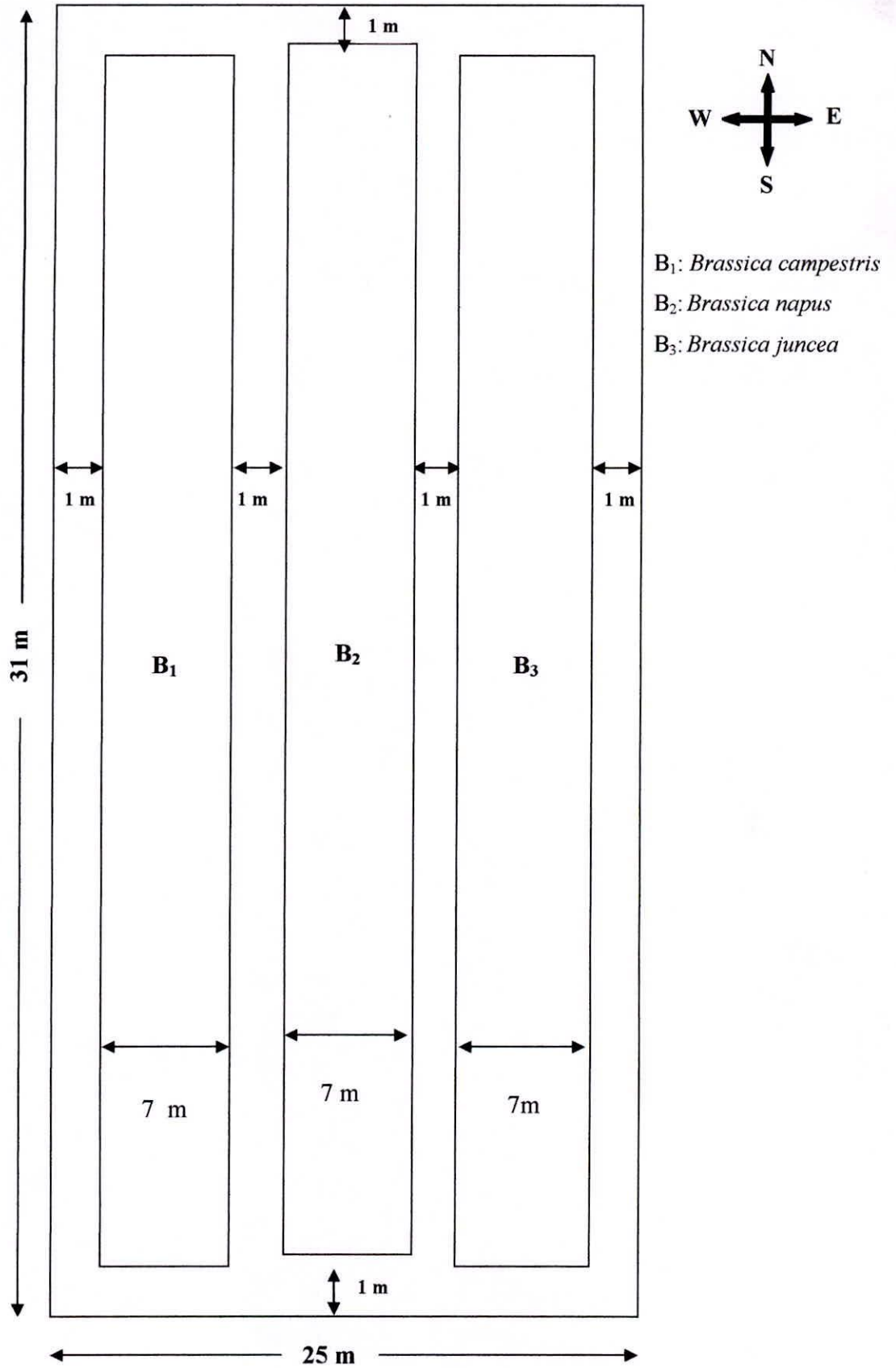


Figure 1. Layout of the experimental plot representing blocks with *Brassica* species.

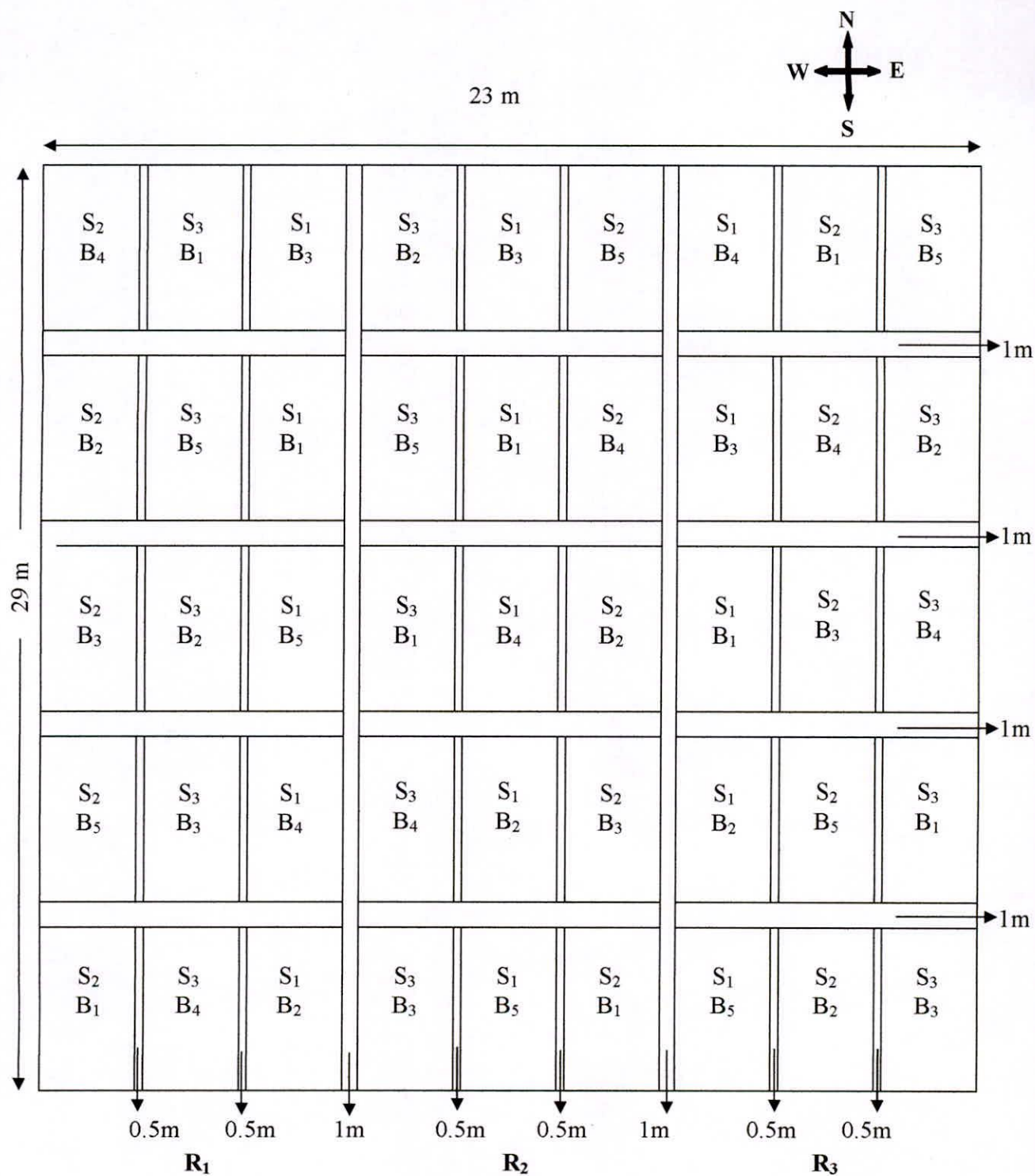


Figure 2. Layout of the experimental plot containing combination of treatments in individual plot.

3.8.2 Collection and incorporation of *Brassica* biomass

The *Brassica* biomass were uprooted at 30 days after sowing and piled separately. Those are then chopped and applied in the wheat field at the rate of 0.5kg green biomass per sq. m as per treatment.

3.8.3 Fertilizer application

The *Brassica* field was fertilized with urea, triple super phosphate (TSP), muriate of potash (MP), gypsum, zinc sulphate and boric acid at the rate of 250-180-100-180-10 and 5 kg ha⁻¹ respectively. The entire amounts of TSP, MP, gypsum, zinc sulphate boric acid and one third amount of urea were applied at final land preparation. The rest amount of urea was not needed to apply on the field as the crop was uprooted after 30 days.

Similarly, the wheat experimental field was fertilized with urea, triple super phosphate (TSP), muriate of potash (MP), 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 (MP), gypsum and zinc sulphate and one third portion 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.

3.8.4 Collection and sowing of seeds

The *Brassica* seeds (BARI Sarisha 11, BARI Sarisha 13 and BARI Sarisha 15) were collected from Oilseed Research Centre, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. At good tilth condition seeds were sown on 3rd November, 2007. Furrows were made with hand rakes for sowing. Seeds were sown continuously in line. The line to line distance was maintained by 30 cm. After sowing seeds were covered with soil and slightly pressed by hand.

The wheat seeds (cv. Shatabdi) were collected from Wheat Research Centre, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Furrows

were made for sowing wheat seed by exploiting the land in proper joe condition. On 4th December, 2007 seeds were sown continuous with maintaining 20 cm line to line distance. After sowing, seeds were covered with soil and pressed slightly by hand.

3.8.5 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 (20, 55, 70 days after sowing). Proper drainage system was maintained to remove the excess amount of water from the plot.

3.8.6 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 attention were undertaken to protect the crop from the attack of parrots, pigeons and other birds.

3.8.7 Harvesting and sampling

The crop was harvested at maturity on March 26, 2008. 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 6m² 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.



3.9 Recording of data

The following data were collected during the study period:

3.9.1 Data regarding weed

1. Weed population
2. Dry weight of weed biomass
3. Weed control efficiency

3.9.2 Data regarding different crop characters and yield of wheat

1. Plant height
2. Number of tillers m^{-2}
3. Number of effective tiller m^{-2}
4. Shoot length
5. Spike length
6. Root length
7. Number of filled grains spike⁻¹
8. Number of unfilled grains spike⁻¹
9. Percentage of filled grain
10. 1000 grain weight
11. Grain yield per hectare
12. Straw yield per hectare
13. Harvest index

3.9.1.1 Weed population

From the 1m^2 area of every plot, the total weeds were uprooted and the species were identified and counted at 30 and 50 days after sowing.

3.9.1.2 Dry weight of weed biomass

The fresh weight of weeds from 1m^2 area of each plot was weighed and oven dried at 80°C 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.

3.9.1.3 Weed control efficiency

Weed control efficiency was calculated with the following formula developed by Sawant and Jadav (1985):

$$\text{Weed control efficiency (WCE)} = \frac{DWC - DWT}{DWC} \times 100$$

Where,

DWC = Dry weight of weeds in unweeded treatment

DWT = Dry weight of weeds in weed control treatment

3.9.2 Yield contributing characters and yield of wheat

3.9.2.1 Plant height

The height of wheat plant was recorded in centimeter (cm) at 30, 50, 70 and 90 days after sowing (DAS). To measure plant height ten plants were randomly selected from each plot and tagged. The height was measured from base of soil surface to tip and mean height was recorded.

3.9.2.2 Number of tillers m⁻²

The total number of tillers per plant was counted. Data were recorded as ten plants were selected at random from the inner rows of each plot starting from 30 to 90 days after sowing at 20 days interval.

3.9.2.3 Number of effective tillers m⁻²

The total number of spikelet bearing tillers m⁻² was counted. Data were recorded as ten plants were selected at random from the inner rows of each plot at 70, 90 days after sowing and at the time of harvest.

3.9.2.4 Shoot length

The measurement was taken from junction of root and shoot to tip of the shoot. Average length of shoot was taken from ten randomly selected plants from inner rows of each plot. Data was recorded from 30 to 90 days after sowing at 20 days interval. Mean was expressed in centimeter (cm).

3.9.2.5 Spike length

The length of spike was measured by using a meter scale. The measurement was taken from base to tip of the spike. Average length of spike was taken from ten randomly selected spikes from inner rows plants of each plot. Data was recorded from 70 days after sowing, 90 days after sowing and at harvest. Mean data was expressed in centimeter (cm).

3.9.2.6 Root length

The length of root was measured by using a meter scale. The measurement was taken from base to tip of the root. Average length of root was taken from ten randomly selected plants from inner rows of each plot. Data was recorded from 30 to 90 days after sowing at 20 days interval. Mean data was expressed in centimeter (cm).

3.9.2.7 Number of filled grains spike⁻¹

The total number of filled grains spike⁻¹ was counted. Data were recorded as the average of ten spike bearing plants selected at random from the inner rows of each plot during the time of harvest.

3.9.2.8 Number of unfilled grains spike⁻¹

The total number of unfilled grains spike⁻¹ was counted. Data were recorded as the average of ten spike bearing plants selected at random from the inner rows of each plot during the time of harvest.

3.9.2.9 Percentage of filled grain

The total number of grains and filled and grains spike⁻¹ was counted firstly then the percentage of filled grain was expressed by using the following formula-

$$\text{Percentage of filled grain (\%)} = \frac{\text{Number of filled grains spike}^{-1}}{\text{Number of total grains spike}^{-1}} \times 100$$

3.9.2.10 1000 grain weight

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

3.9.2.11 Grain yield

After threshing, proper drying (12% moisture level) and cleaning, yield of each sample plot was weighed and values were converted to t ha⁻¹.

3.9.2.12 Straw yield

Straw weight of each plot was weighed after threshing and drying and converted them into t ha⁻¹.

3.9.2.13 Harvest index

Harvest index (%) was determined by the following equation as of Gardner *et al.*, 1985).

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

3.10 Statistical analysis

The collected data were compiled and analyzed by split plot design to find out the statistical significance among the level of factors. The collected data were analyzed by MSTAT-C software. The means for all recorded data were calculated and the analyses of variance (ANOVA) 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

This chapter comprised presentation and discussion of the results obtained from the study to find out the effect of *Brassica* biomass by different incorporation methods on weed control and yield of wheat cv. Shatabdi. The results of the weed parameters, crop characters which are influenced by different treatment to control weeds by different methods of incorporation have been presented and discussed in this chapter.

4.1 Weed control

4.1.1 Weed Species in the Experimental Field

It is a common phenomenon that plants compete with numerous weeds under favourable condition. Plant-weed competition increased when the density of weeds increases. Twelve weed species belongs to 7 families were found infested in the experimental field. *Cyperous rotundus*, *Cynodon dactylon*, *Eleusine indica*, *Digitaria sanguinalis*, *Chenopodium album* were found with major population among the 12 weed species population. There were five species of grass, two were sedge and five under broad leaved (Table 1).

Weeds can eventually germinates in any field in a favourable condition. Some different type of adjacent field such as fellow land, experimental field on fertilizer and variety & irrigation had been selected to find the types of weed species grow in the field. Total of 9 weed species had been found unavailable in this experimental field which was numerous in other field condition. The name, common name, scientific name, family, life cycle and type of those weed species are shown in Table 1.

Table 1. List of weeds with common name, scientific name, family, life cycle and type that were available and unavailable in the experimental plot

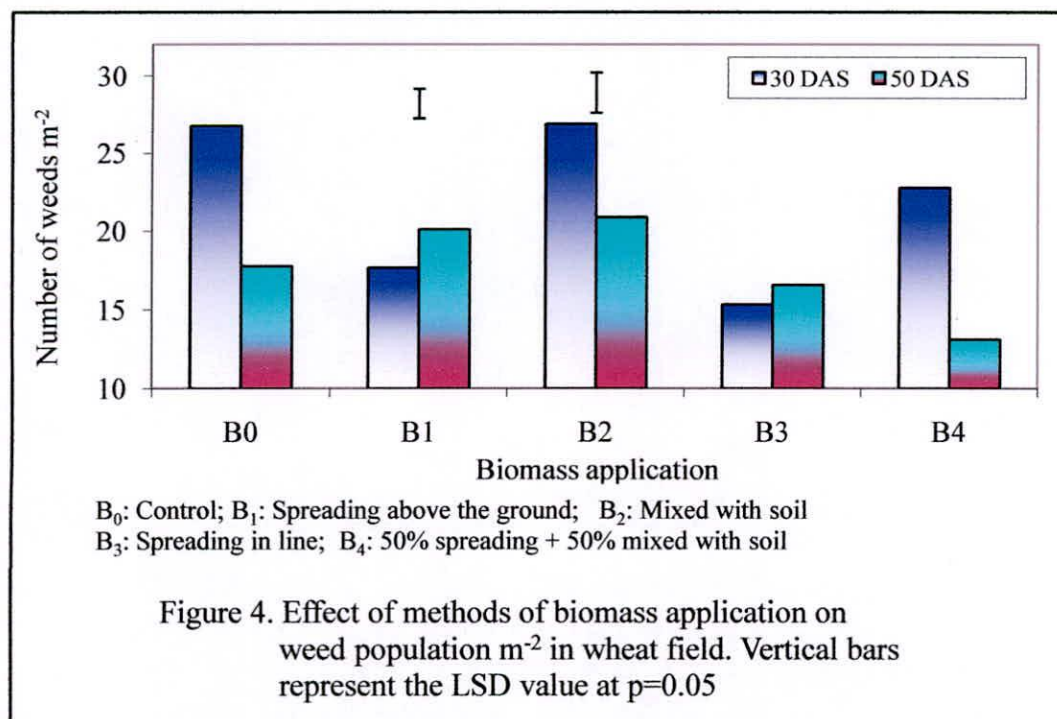
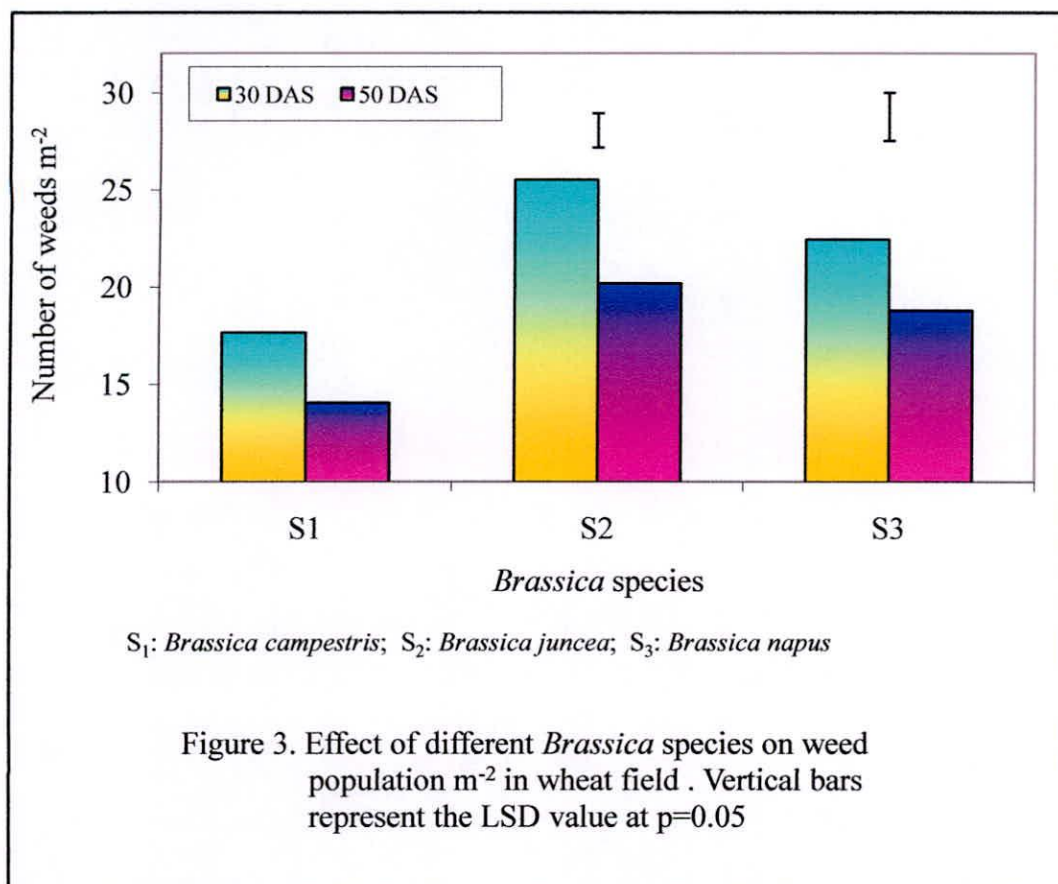
Sl. No.	Local Name	Common Name	Scientific Name	Family	Life Cycle
Weeds available in the experimental plot					
1.	Mutha	Nut sedge	<i>Cyperus rotundus</i>	Cyperaceae	Annual
2.	Chapra	Goose grass	<i>Eleusine indica</i>	Gramineae	Perennial
3.	Durba	Bermuda grass	<i>Cynodon dactylon</i>	Gramineae	Perennial
4.	Anguli ghas	Scrab grass	<i>Digitaria sanguinalis</i>	Gramineae	Annual
5.	Bon Mosur	Wild lentil	<i>Vicia sativa</i>	Leguminosae	Annual
6.	Choto Shama	Jungle rice	<i>Echinochloa colonum</i>	Gramineae	Annual
7.	Bathua	Lambsquarters	<i>Chenopodium album</i>	Chenopodiaceae	Annual
8.	Tita Begun	Tita Begun	<i>Solanum torvum</i>	Solanaceae	Annual
9.	Chatidhara	Flat cyperus	<i>Cyperus compressus</i>	Cyperaceae	Annual
10.	Shetodron	Leucas	<i>Leucas aspera</i>	Labiatae	Annual
11.	Malancha	Alligator weed	<i>Alternanthera philoxeroides</i>	Amaranthaceae	Annual
12.	Bon China	Torpedo grass	<i>Panicum repens</i>	Gramineae	Perennial
Weeds unavailable in the experimental plot compare to adjacent area					
1.	Khet papri	Khet Papri	<i>Lindernia procumbens</i>	Scrophulariaceae	Annual
2.	Hati shur	Wild Heliotrop	<i>Heliotropium indicum</i>	Boraginaceae	Annual
3.	Kata Notae	Spiny Pig Weed	<i>Amaranthus spinosus</i>	Amaranthaceae	Annual
4.	Shak Notae	Pig Weed	<i>Amaranthus viridis</i>	Amaranthaceae	Annual
5.	Bish Katali	Smart Weed/Water pepper	<i>Polygonum hydropiper</i>	Polygonaceae	Annual
6.	Shet Morog	White Cock's Comb	<i>Celosia argentina</i>	Amaranthaceae	Annual
7.	Chagla Gacha	Goat Weed	<i>Ageratum conyzoides</i>	Compositae	Annual
8.	Bon Sarisha	Wild Mustard	<i>Brassica kaber</i>	Cruciferae	Annual
9.	Choto Anguli	Small Crabgrass	<i>Digitaria ischamaemum</i>	Gramineae	Annual

4.1.2 Weed Population

Weed population varied considerably due to different weed control treatment (Appendix III). At 30 DAS, *Brassica* species was insignificantly affected on weed population. It was found that the maximum numbers of weeds (25.53 m^{-2}) were found in the plot treated with *Brassica juncea* which is 44.81% higher than the least number of weed population (17.67 m^{-2}) from *Brassica campestris* (Figure 3). *Brassica napus* treated plot showed 27.39% more number of weeds than *Brassica campestris*. At 50 DAS, *Brassica juncea* also showed the highest weed population (20.20 m^{-2}). There was no significant difference found among the *Brassica* species though *Brassica campestris* showed the best effect on weed control as there was the least number of weed population (14.07 m^{-2}). It is clearly seen that *Brassica juncea* had 43.57% and *Brassica napus* had 28.43% higher weed population over *Brassica campestris*. Mirabelli *et al.* (2004) found that cover crops resulted in clear weed suppression in the following crop. Penfold (2003) reported that 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.

Weed population also varied significantly due to different incorporation methods of *Brassica* biomass (Appendix III). At 30 DAS, the lowest weed population (15.33 m^{-2}) was seen by B_3 (spreading in line) (Figure 4). The highest weed population (26.89 m^{-2}) was found in the B_2 (mixed with soil) plot which was statistically similar with the control (no biomass application) followed by B_4 (50% spreading + 50% mixed with soil) and B_1 (spreading above the ground). The B_2 (mixed with soil) showed 75.41% higher weed population over B_3 (spreading in line). The control plot had 74.69% higher over B_3 treatment. The B_4 and B_1 had 48.60% and 15.26% higher weed population than B_3 respectively. At 50 DAS, there was no significant difference observed due to incorporation methods. The maximum (20.89 m^{-2}) weed population was found in B_2 (mixed with soil) whereas B_4 (50% spreading + 50% mixed with soil) showed minimum (13.11 m^{-2}) population. Mixed with soil method had 59.34% higher weed population over B_4 . The B_1 (spreading above the ground), B_0 (control) and B_3 (spreading in line)





showed 53.39%, 35.62% & 33.94% higher weed population over B₄ (50% spreading + 50% mixed with soil), respectively. Cheema *et al.* (2003) reported that conventional methods like hand weeding and herbicides, though effective in weed control, were uneconomical due to higher costs. Maiksteniene and Arlauskiene (2007) reported that during the cereal post-harvest period red clover performed best at suppressing weeds, and its positive effect persisted in the year following incorporation of intercrops biomass. Xuan *et al.* (2005) reported that 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.

There was significant effect on weed population by the combined effect of *Brassica* species and different incorporation methods (Appendix III). At 30 DAS the maximum (37.33 m⁻²) weed population was observed in S₂B₀ (*Brassica juncea* with control) treatment combination which was 173.08% higher than the lowest (13.67 m⁻²) population observed in S₃B₃ (*Brassica napus* with spreading in line) treatment combination (Table 3). But at 50 DAS, S₃B₂ (*Brassica napus* with mixed with soil) treatment showed the maximum (40.00 m⁻²) weed population whereas S₁B₂ (*Brassica campestris* with mixed with soil) showed the lowest (8.667 m⁻²) weed population. There was 361.53% higher weed population observed at S₃B₂ than S₁B₂.

4.1.3 Dry weight of weed biomass

The dry weight of weed biomass was significantly affected by *Brassica* sp (Appendix III). The highest weed biomass (1.72 gm⁻² and 1.44 gm⁻²) were obtained in S₂ (*Brassica juncea*) at 30 DAS and S₃ (*Brassica napus*) at 50 DAS respectively (Table 2). At 30 DAS, both *Brassica campestris* (S₁) and *Brassica napus* (S₃) gave the similar lowest (1.16 gm⁻²) weed biomass but at 50 DAS *Brassica juncea* gave the lowest (0.96 gm⁻²) weed biomass that similar to *Brassica campestris*. At 30 DAS, both S₁ and S₃ gave 48.27% but at 50 DAS, S₂ gave 50% lower density over the highest weed density. Khan *et al.* (2005) reported that biomass yield varied due to different species.

Table 2. Main effect of different *Brassica* species and incorporation methods on dry weight of weed biomass and weed control efficiency in wheat field

Treatment	Dry weight of weed biomass (gm ⁻²)		Weed control efficiency (%) at	
	30 DAS	50 DAS	30 DAS	50 DAS
<i>Brassica</i> species				
S ₁	1.16 b	1.07 b	-93.90	30.86
S ₂	1.72 a	0.96 b	15.57	42.27
S ₃	1.16 b	1.44 a	6.77	-22.60
SE	0.081	0.048	44.283	20.87
Incorporation methods				
B ₀	1.49 a	1.66 a	0.00	0.00
B ₁	0.89 b	1.10 ab	-1.15	24.32
B ₂	1.59 a	1.31 a	-27.89	-13.60
B ₃	1.11 ab	0.93 b	-16.97	29.59
B ₄	1.65 a	0.80 b	-73.27	43.92
SE	0.192	0.176	21.40	19.31
CV(%)	12.33	18.25	-269.06	343.86

In a column mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

S₁: *Brassica campestris*

S₂: *Brassica juncea*

S₃: *Brassica napus*

B₀: Control (no biomass application)

B₁: Spreading above the ground

B₂: Mixed with soil

B₃: Spreading in line

B₄: 50% spreading + 50% mixed with soil

Table 3. Combined effect of different *Brassica* species and incorporation methods on weed population m^{-2} , dry weight of weed biomass and weed control efficiency in wheat field

Treatment	Weed population (No. m^{-2}) at		Dry weight of weed biomass (gm^{-2})		Weed control efficiency (%) at	
	30 DAS	50 DAS	30 DAS	50 DAS	30 DAS	50 DAS
S ₁ B ₀	17.00	19.33	0.91 cd	1.78 ab	0.00	0.00
S ₁ B ₁	15.67	17.67	1.01 cd	1.31 bcd	-99.03	1.89
S ₁ B ₂	15.33	8.67	0.93 cd	1.01 bcd	-53.43	35.00
S ₁ B ₃	17.67	15.67	1.13 cd	0.78 cd	-107.23	49.52
S ₁ B ₄	22.67	9.00	1.80 abc	0.51 d	-209.83	67.90
S ₂ B ₀	37.33	22.00	2.31 ab	1.71 ab	0.00	0.00
S ₂ B ₁	21.00	29.67	0.92 cd	1.03 bcd	54.85	39.66
S ₂ B ₂	36.67	14.00	2.68 a	0.47 d	-29.24	70.68
S ₂ B ₃	14.67	19.00	1.26 cd	0.99 bcd	33.10	39.11
S ₂ B ₄	18.00	16.33	1.44 b	0.61 d	19.13	61.91
S ₃ B ₀	26.00	12.00	1.26 cd	1.48 bc	0.00	0.00
S ₃ B ₁	16.33	13.00	0.74 d	0.95 bcd	40.72	31.41
S ₃ B ₂	28.67	40.00	1.16 cd	2.46 a	-0.99	-146.48
S ₃ B ₃	13.67	15.00	0.93 cd	1.04 bcd	23.23	0.13
S ₃ B ₄	27.67	14.00	1.72 bc	1.29 bcd	-29.12	1.95
SE	5.572	7.623	0.401	0.366	37.06	33.44
CV(%)	44.09	74.65	12.33	18.25	-269.06	343.86

In a column mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

S₁: *Brassica campestris*

S₂: *Brassica juncea*

S₃: *Brassica napus*

B₀: Control (no biomass application)

B₁: Spreading above the ground

B₂: Mixed with soil

B₃: Spreading in line

B₄: 50% spreading + 50% mixed with soil

There was significant variation observed among different incorporation methods in weed biomass (Appendix III). At 30 DAS, the highest (1.65 gm^{-2}) weed biomass was found in 50% spreading + 50% mixed with soil (B_4) treatment which is statistically similar with B_2 (mixed with soil) and B_0 (control). The lowest (0.89 gm^{-2}) weed biomass was found in B_1 (Spreading above the ground) which was 40.27% lower than control (Table 2). At 50 DAS, the highest (1.66 gm^{-2}) weed biomass was obtained in B_0 (control) treatment which was statistically similar to B_2 (mixed with soil). Meschede (2007) reported that biomass accumulation by the covers was inversely proportional to weed biomass.

The combined effect between *Brassica* sp. & different incorporation methods had significant effect on total weed biomass over time (Appendix III). At 30 DAS, the treatment S_2B_2 (*Brassica juncea* with mixed with soil) contributed the highest (2.68 gm^{-2}) weed biomass which was statistically similar with S_2B_0 (*Brassica juncea* with control) and was statistically higher than the biomass obtained in the treatment combinations (Table 3). The lowest (0.74 gm^{-2}) weed biomass was obtained in the treatment S_3B_1 (*Brassica napus* with spreading above the ground) whereas, at 50 DAS, the treatment combination S_3B_3 (*Brassica napus* mixed with soil) produced the highest (2.46 gm^{-2}) weed biomass which was statistically similar to S_2B_0 treatment combination. The lowest (0.51 gm^{-2}) weed biomass was produced by the treatment combination S_1B_4 (*Brassica campestris* with 50% spreading + 50% mixed with soil).

4.1.4 Weed control efficiency

The weed control efficiency indicates the percentage of weed in comparison to control. Table 2 indicates that at 30 DAS, there was no significant difference due to *Brassica* species. Among them, *Brassica juncea* showed highest (15.57%) weed control efficiency while *Brassica campestris* showed lowest with negative (93.30%) efficiency. At 50 DAS, there was no significant difference. *Brassica juncea* had maximum (42.27%) efficiency. It was observed that, *Brassica campestris* was 30.86% efficient in weed control but it was found negative at 30 DAS. On the other hand, *Brassica napus* was efficient (6.77%) at 30 DAS but it

was inefficient (-22.60%) at 50 DAS. Rudrappa *et al.* (2007) reported similar results.

Different incorporation methods differed for weed control efficiency both at 30 DAS and 50 DAS. At 30 DAS, there was no efficiency observed over control. The most inefficient treatment (-73.27%) was B₄ (50% spreading + 50% mixed with soil) but it was highest (43.92%) in efficiency at 50 DAS which was statistically similar with B₃ (spreading in line) and B₁ (spreading above the ground) to control weed (29.59%, 24.32% respectively). The B₂ (mixed with soil) showed the inefficiency (-13.60%) over control (Table 2).

Different combined effect of *Brassica* sp. was recorded for different incorporation methods. At 30 DAS, S₂B₁ (*Brassica juncea* with spreading above the ground) was mostly efficient (54.85%) with no significant difference to S₃B₁ (*Brassica napus* with spreading above the ground) and S₂B₃ (*Brassica juncea* with spreading in line) treatment combination (40.72% & 33.10% respectively). There was statistical similarity of other treatments (Table 3). At 50 DAS, the treatment combination S₂B₂ (*Brassica juncea* with mixed with soil) showed the highest (70.68%) efficiency with statistical similarity with other treatment combinations except S₃B₂ (*Brassica napus* with mixed with soil) which only showed inefficiency (-146.48%) in weed control.

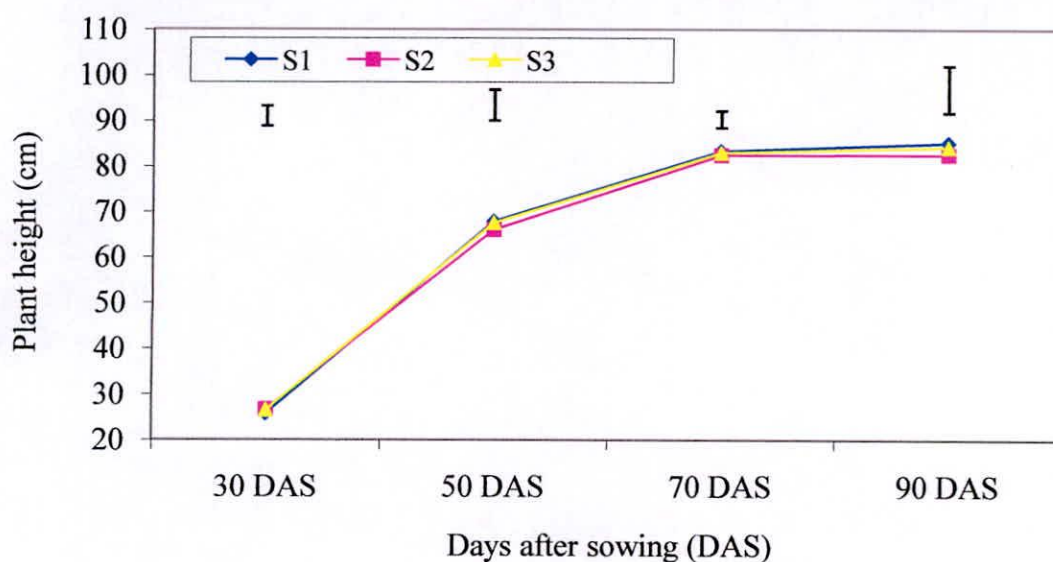
4.2 Crop Growth Parameters

4.2.1 Plant height

The plant height had no significant effect by the treatment of *Brassica* sp. during the period from 30 to 90 DAS (Appendix IV). At 30 DAS S₂ (*Brassica juncea*) produced the numerically tallest plant (26.62 cm) among the species whereas S₁ (*Brassica campestris*) produced the tallest (67.85 cm, 83.29 cm and 85.15 cm) plant at 50, 70 and 90 DAS (Figure 5). The shortest plant (25.73) was observed from S₁ at 30 DAS but at 50, 70, 90 DAS the shortest plant (66.03 cm, 82.37 cm and 82.53 cm) was observed from S₂. The result indicates that there was no effect of *Brassica* species on plant height of wheat.

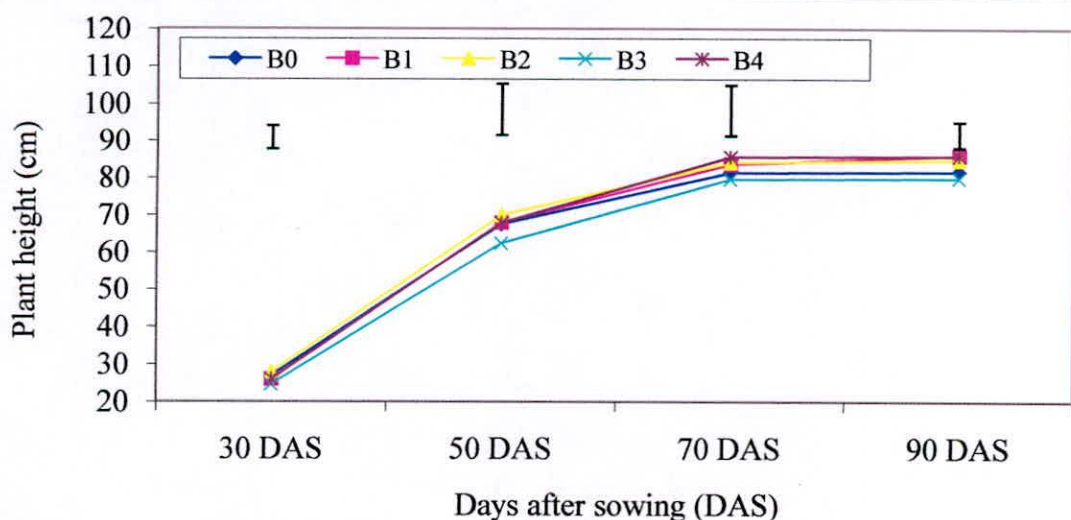
The plant height was significantly affected by different incorporation methods during the period of 30 to 90 DAS (Appendix IV). At 30 DAS, the tallest plant (27.92 cm) was recorded from B₂ (mixed with soil) which was statistically similar (26.94 cm, 25.99 cm and 25.92 cm) to B₀ (control), B₄ (50% spreading + 50% mixed with soil) and B₁ (spreading above the ground), respectively (Figure 6). At 50 DAS, the tallest plant (69.98 cm) was recorded from B₂ which was statistically similar (67.97 cm, 67.85 cm and 67.55 cm) to B₁, B₄ and B₀, respectively. At 70 DAS, the tallest plant (85.61 cm) was recorded from B₄ which was statistically similar (84.17 cm, 83.62 cm and 81.34 cm) to B₂, B₁ and B₀, respectively. At 90 DAS, the tallest plant (86.08 cm) was recorded from B₁ which was statistically similar (85.90 cm and 84.83 cm) to B₄ and B₂, respectively. On the other hand, B₃ (spreading in line) produced the shortest plant at 30 DAS (24.62 cm), 50 DAS (62.39 cm), 70 DAS (79.60 cm), 90 DAS (79.69 cm).

Combined effect of *Brassica* species with different incorporation method had significant effect on plant height at 30, 50 and 90 DAS but insignificant at 70 DAS (Appendix IV). Plant height increased over time in all the treatment combinations but did not show similar performance at all days after sowing (DAS). At 30 DAS, S₂B₂ (*Brassica napus* with mixed with soil) showed tallest plant (29.07 cm) which was statistically similar to all other treatments whereas, S₁B₀ (*Brassica campestris* with control) showed the shortest plant (24.14 cm). At 50 DAS, S₁B₄ (*Brassica campestris* with 50% spreading + 50% mix with soil) given the tallest plant (71.48 cm) which was also statistically similar to other treatments and S₂B₃ (*Brassica napus* with spreading in line) showed the shortest plant (61.44 cm). At 70 DAS, S₁B₂ produced numerically the tallest plant (87.27 cm) and S₂B₃ (*Brassica napus* with spreading in line) produced the shortest plant (77.87 cm). *Brassica juncea* with spreading above the ground (S₃B₁) had the tallest plant (89.33 cm) and *Brassica juncea* with spreading in line (S₃B₃) had the shortest plant (79.13 cm) at 90 DAS (Table 4). The result indicates that there was no specific treatment combinations precisely affect on plant height.



S₁: *Brassica campestris*; S₂: *Brassica juncea*; S₃: *Brassica napus*

Figure 5. Effect of different *Brassica* species on plant height of wheat. Vertical bars represent the LSD value at $p=0.05$



B₀: Control; B₁: Spreading above the ground; B₂: Mixed with soil
B₃: Spreading in line; B₄: 50% spreading + 50% mixed with soil

Figure 6. Effect of methods of biomass application on plant height of wheat. Vertical bars represent the LSD value at $p=0.05$



Table 4. Combined effect of different *Brassica* species and incorporation methods on plant height at different days after sowing of wheat

Treatment	Plant height (cm) at			
	30 DAS	50 DAS	70 DAS	90 DAS
S ₁ B ₀	24.14 c	66.97 ab	81.13	83.20 cd
S ₁ B ₁	25.67 abc	68.01 ab	81.53	83.00 cd
S ₁ B ₂	27.86 abc	71.27 a	87.27	88.00 ab
S ₁ B ₃	24.66 bc	61.53 b	80.17	81.13 cd
S ₁ B ₄	26.32 abc	71.48 a	86.33	85.40 abc
S ₂ B ₀	28.53 ab	67.35 ab	79.73	79.80 d
S ₂ B ₁	25.71 abc	66.52 ab	84.27	85.90 abc
S ₂ B ₂	29.07 a	68.53 ab	86.27	84.67 bc
S ₂ B ₃	24.49 bc	61.44 b	77.87	79.60 d
S ₂ B ₄	25.31 abc	66.29 ab	83.73	83.07 cd
S ₃ B ₀	28.14 abc	68.31 ab	83.17	82.63 cd
S ₃ B ₁	26.39 abc	69.38 ab	85.07	89.33 a
S ₃ B ₂	26.84 abc	70.15 ab	78.97	81.83 cd
S ₃ B ₃	24.71 bc	64.20 ab	80.75	79.13 d
S ₃ B ₄	26.35 abc	65.79 ab	86.77	88.03 ab
SE	1.272	2.788	2.741	1.424
CV(%)	8.39	7.19	5.73	2.95

In a column mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

S₁: *Brassica campestris*

S₂: *Brassica juncea*

S₃: *Brassica napus*

B₀: Control (no biomass application)

B₁: Spreading above the ground

B₂: Mixed with soil

B₃: Spreading in line

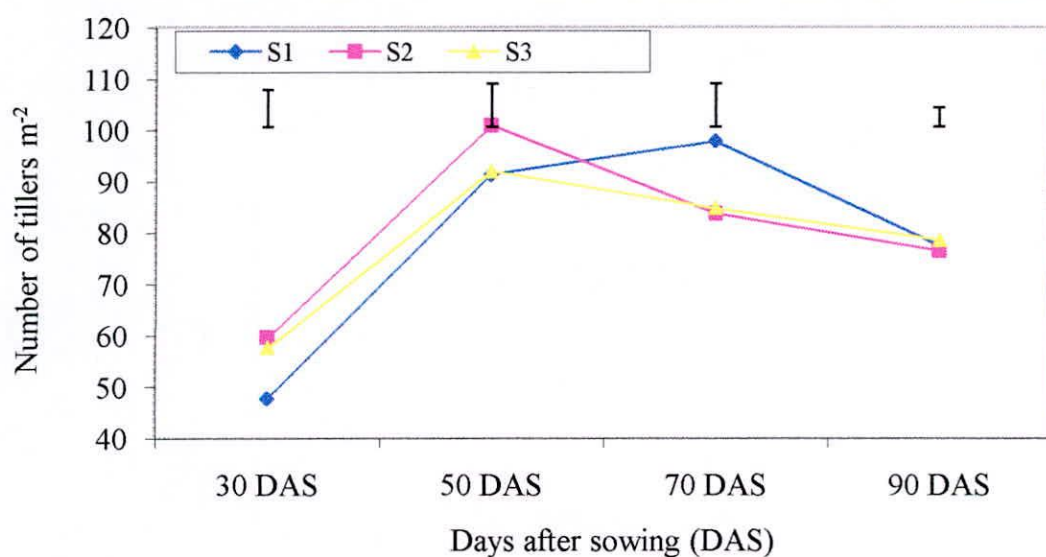
B₄: 50% spreading + 50% mixed with soil

4.2.2 Number of tillers m⁻²

Number of tillers m⁻² was affected non-significantly at 30 DAS, 50 DAS, 70 DAS and 90 DAS (Appendix V). The number of tillers m⁻² increased gradually for 30 and 50 DAS for *Brassica* species thereafter showed a decreasing trend for S₂ (*Brassica juncea*) and S₃ (*Brassica napus*) at 70 DAS and also for all *Brassica* treatments at 90 DAS but S₁ showed increasing trend upto 70 DAS (Figure 7). The number of tillers m⁻² decreased due to mortality of ineffective tillers at later stage. Among the *Brassica* specie S₂ (*Brassica juncea*) showed the highest number of tillers m⁻² at 30 DAS (59.60), 50 DAS (100.87) and 90 DAS (78.67) but the lowest number of tillers m⁻² (83.73) at 70 DAS. The S₁ (*Brassica campestris*) showed the highest number of tillers m⁻² (97.87) at 70 DAS but lowest at 30 DAS (47.73) & 90 DAS (76.53). At 50 DAS, S₃ (*Brassica napus*) showed was the lowest number of tillers m⁻² (91.33).

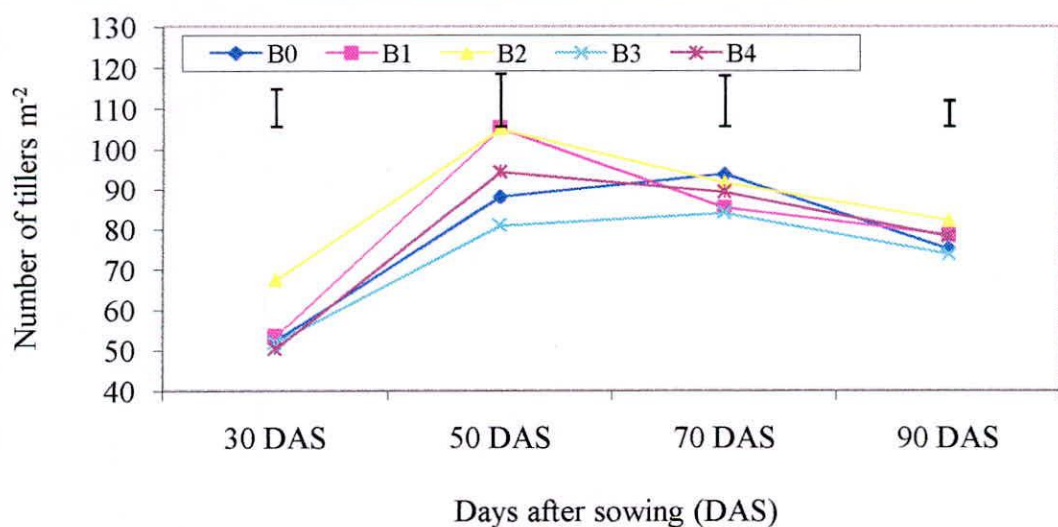
Number of tiller m⁻² was insignificantly affected by different incorporation methods at 30 DAS, 50 DAS, 70 DAS and 90 DAS (Appendix V). The highest number of tillers m⁻² (67.33, 105.22 & 82.22) was produced by B₂ (mixed with soil) at 30 DAS and 50 DAS and 90 DAS, respectively but at 70 DAS B₀ (control) was highest (93.78). The lowest number (50.22, 80.89, 84.00 and 73.78) was produced by B₃ (spreading in line), respectively whereas B₀ (control) (Figure 8).

The combined effect of *Brassica* sp. and different incorporation methods non-significantly influenced the total number of tillers m⁻² at different DAS (Appendix V). At 30 DAS, S₂B₂ (*Brassica juncea* with mixed with soil) had the highest number of tillers m⁻² (77.67) and S₁B₀ (*Brassica campestris* with control) had the lowest (39.33). Treatment S₂B₁ (*Brassica juncea* with spreading above the ground) showed the highest number of tillers m⁻² (115.67) at 50 DAS but S₃B₃ (*Brassica napus* with spreading in line) showed the lowest number of tillers m⁻² (75.33). At 70 DAS, S₁B₀ given the highest number of tiller m⁻² (110.67) and S₂B₃ (*Brassica juncea* with spreading in line) given the lowest (72.00). It was highest at 90 DAS (88.00 for S₃B₁ (*Brassica napus* with spreading above the ground) and the lowest number of tiller m⁻² (69.00) for S₁B₃ at 90 DAS (Table 5).



S₁: *Brassica campestris*; S₂: *Brassica juncea*; S₃: *Brassica napus*

Figure 7. Effect of different *Brassica* species on number of tillers m⁻² in wheat field. Vertical bars represent the LSD value at p=0.05



B₀: Control; B₁: Spreading above the ground; B₂: Mixed with soil
B₃: Spreading in line; B₄: 50% spreading + 50% mixed with soil

Figure 8. Effect of methods of biomass application on number of tillers m⁻² in wheat field. Vertical bars represent the LSD value at p=0.05

Table 5. Combined effect of different *Brassica* species and incorporation methods on number of tillers m⁻² at different days after sowing of wheat

Treatment	Number of tillers m ⁻² at			
	30 DAS	50 DAS	70 DAS	90 DAS
S ₁ B ₀	39.33	84.00	110.67	81.33
S ₁ B ₁	48.00	85.00	81.33	78.67
S ₁ B ₂	47.33	99.67	94.67	82.67
S ₁ B ₃	54.67	81.00	101.33	69.00
S ₁ B ₄	49.33	107.00	101.33	76.00
S ₂ B ₀	59.33	97.00	80.00	74.67
S ₂ B ₁	50.00	115.67	88.00	69.33
S ₂ B ₂	77.67	114.00	94.67	84.00
S ₂ B ₃	58.00	86.33	72.00	78.67
S ₂ B ₄	53.33	91.33	84.00	76.00
S ₃ B ₀	58.00	83.33	90.67	69.33
S ₃ B ₁	62.00	115.00	86.67	88.00
S ₃ B ₂	77.33	101.33	85.33	80.00
S ₃ B ₃	42.67	75.33	78.67	73.33
S ₃ B ₄	48.00	84.67	82.67	82.67
SE	10.406	13.623	9.673	6.903
CV(%)	32.78	24.91	18.87	15.41

S₁: *Brassica campestris*

S₂: *Brassica juncea*

S₃: *Brassica napus*

B₀: Control (no biomass application)

B₁: Spreading above the ground

B₂: Mixed with soil

B₃: Spreading in line

B₄: 50% spreading + 50% mixed with soil

4.2.3 Number of effective tillers m^{-2}

Number of effective tillers m^{-2} showed non-significantly variation for 70 DAS, 90 DAS and at harvest (Appendix VI). The number of effective tillers m^{-2} decreased gradually at 70, 90 DAS and at harvest for *Brassica* species (Table 6). At 70 DAS among the *Brassica* specie S_1 (*Brassica campestris*) produced the highest number of effective tillers m^{-2} (72.53) but the lowest number of effective tillers m^{-2} (64.53) was obtained from S_2 (*Brassica juncea*). At 90 DAS numerically the highest number of effective tillers m^{-2} (57.87) was recorded from S_1 and the lowest number of effective tillers m^{-2} (54.53) was recorded from S_3 . At harvest, S_1 gave numerically the highest number of effective tillers m^{-2} (53.20), while the lowest number of effective tillers m^{-2} (50.53) was recorded from S_3 .

Number of effective tillers m^{-2} was non-significantly affected by different incorporation methods at harvest but insignificant at 70 DAS, 90 DAS and harvest (Appendix VI). At 70 DAS numerically the highest number of effective tillers m^{-2} (73.78) was produced by B_4 (50% spreading + 50% mixed with soil) but the lowest number (61.33) was recorded from B_3 (spreading in line). At 90 DAS, the highest number of effective tillers m^{-2} (61.33) was recorded from B_2 (mixed with soil) and the lowest number (52.22) was observed from B_0 (control). At harvest, the highest number of effective tillers m^{-2} (56.44) was obtained from B_2 , whereas the lowest number of effective tillers m^{-2} (48.44) was recorded from B_0 (Table 6).

The combined effect of *Brassica* sp. and different incorporation methods non-significantly influenced the total number of tillers m^{-2} at different DAS (Appendix VI). At 70 DAS, S_3B_0 (*Brassica campestris* with control) had the highest number of effective tillers m^{-2} (81.33) and S_2B_0 (*Brassica juncea* with control) had the lowest number (48.00). At 90 DAS, S_2B_2 (*Brassica juncea* with mixed with soil) produced the highest number of effective tillers m^{-2} (68.00) but S_3B_0 (*Brassica napus* with control) showed the lowest number of effective tillers m^{-2} (47.33). At harvest, S_2B_2 (*Brassica juncea* with mixed with soil) given the highest number of effective tiller m^{-2} (63.33) and S_3B_3 (*Brassica napus* with spreading in line) given the lowest number (44.67) (Table 7).



Table 6. Main effect of different *Brassica* species and incorporation methods on number of effective tillers m⁻² at different days after sowing of wheat

Treatment	Number of effective tillers m ⁻² at		
	70 DAS	90 DAS	Harvest
<i>Brassica</i> species			
S ₁	72.53	57.87	53.20
S ₂	64.53	56.53	53.00
S ₃	68.27	54.53	50.53
SE	2.188	5.490	4.906
Incorporation methods			
B ₀	69.33	52.22	48.44
B ₁	68.89	56.44	52.00
B ₂	68.89	61.33	56.44
B ₃	61.33	53.78	49.67
B ₄	73.78	57.78	54.67
SE	4.282	4.750	4.363
CV(%)	18.77	25.31	25.05

S₁: *Brassica campestris*

S₂: *Brassica juncea*

S₃: *Brassica napus*

B₀: Control (no biomass application)

B₁: Spreading above the ground

B₂: Mixed with soil

B₃: Spreading in line

B₄: 50% spreading + 50% mixed with soil

Table 7. Combined effect of different *Brassica* species and incorporation methods on number of effective tillers m⁻² at different days after sowing of wheat

Treatment	Number of effective tillers m ⁻² at		
	70 DAS	90 DAS	Harvest
S ₁ B ₀	81.33	60.00	53.67
S ₁ B ₁	61.33	53.33	49.33
S ₁ B ₂	72.00	65.33	59.33
S ₁ B ₃	72.00	50.67	47.00
S ₁ B ₄	76.00	60.00	56.67
S ₂ B ₀	48.00	49.33	46.00
S ₂ B ₁	68.00	53.33	49.67
S ₂ B ₂	77.33	68.00	63.33
S ₂ B ₃	56.00	61.33	57.33
S ₂ B ₄	73.33	50.67	48.67
S ₃ B ₀	78.67	47.33	45.67
S ₃ B ₁	77.33	62.67	57.00
S ₃ B ₂	57.33	50.67	46.67
S ₃ B ₃	56.00	49.33	44.67
S ₃ B ₄	72.00	62.67	58.67
SE	7.416	8.227	7.557
CV(%)	18.77	25.31	25.05

S₁: *Brassica campestris*

S₂: *Brassica juncea*

S₃: *Brassica napus*

B₀: Control (no biomass application)

B₁: Spreading above the ground

B₂: Mixed with soil

B₃: Spreading in line

B₄: 50% spreading + 50% mixed with soil

4.2.4 Shoot length

Shoot length differed significantly for 50 and 90 DAS and non-significant for 30 and 70 DAS (Appendix VII). Shoot length showed increasing trend starting from 30 DAS and continued upto 90 DAS. At 30 DAS, among the *Brassica* specie S_2 (*Brassica juncea*) produced the numerically maximum shoot length (27.81 cm) but the minimum shoot length (26.82 cm) was obtained from S_1 (*Brassica campestris*). At 50 DAS, significantly the highest shoot length (70.15 cm) was recorded from S_1 which was statistically similar (69.30 cm) to S_3 and the minimum shoot length (68.27 cm) was recorded from S_2 . At 70 DAS, the numerical maximum shoot length (87.21 cm) was recorded from S_1 and the minimum length (86.51 cm) was recorded from S_2 . At 90 DAS, the highest shoot length (88.09 cm) was recorded from S_3 which was statistically similar (87.56 cm) to S_1 and the minimum length (85.87 cm) was recorded from S_2 (Table 8). Javaid *et al.* (2006) reported insignificant effects on shoot length of all the test crops.

Shoot length of wheat significantly varied by different incorporation methods at 30, 50, 70 and 90 DAS (Appendix VII). At 30 DAS, the maximum shoot length (28.96 cm) was recorded from B_2 (mixed with soil) which was statistically similar (28.01 cm, 27.35 cm and 27.12 cm) with B_0 (control), B_1 (spreading above the ground) and B_4 , respectively, while the minimum length (25.93 cm) was recorded from B_3 (spreading in line). At 50 DAS, the maximum shoot length (72.31 cm) was recorded from B_2 which was statistically similar (70.33 cm, 69.92 cm and 69.60 cm) with B_1 , B_4 and B_0 , respectively; while the minimum length (64.04 cm) was recorded from B_3 . At 70 DAS, the maximum length (89.73 cm) was recorded from B_4 which was statistically similar (88.23 cm, 87.57 cm and 85.46 cm) with B_2 , B_1 and B_0 , respectively while the minimum shoot length (83.45 cm) was recorded from B_3 . At 90 DAS, the maximum length (89.65 cm) was recorded from B_1 which was statistically similar (89.08 cm and 87.88 cm) with B_4 and B_2 , respectively while the minimum length (84.10 cm) was recorded from B_3 which was statistically similar (85.17 cm) to B_0 (Table 8). Bhatt and Todaria (1990) reported that shoot length were depressed by agroforestry tree crops.

Table 8. Main effect of different *Brassica* species and incorporation methods on shoot length at different days after sowing of wheat

Treatment	Shoot length (cm) at			
	30 DAS	50 DAS	70 DAS	90 DAS
<i>Brassica</i> species				
S ₁	26.82	70.15 a	87.21	87.56 a
S ₂	27.81	68.27 b	86.51	85.87 b
S ₃	27.79	69.30 a	86.94	88.09 a
SE	1.453	0.987	0.851	0.378
Incorporation methods				
B ₀	28.01 ab	69.60 a	85.46 ab	85.17 b
B ₁	27.35 ab	70.33 a	87.57 ab	89.65 a
B ₂	28.96 a	72.31 a	88.23 ab	87.88 a
B ₃	25.93 b	64.04 b	83.45 b	84.10 b
B ₄	27.12 ab	69.92 a	89.73 a	89.08 a
SE	0.768	1.705	1.636	0.916
CV(%)	8.38	7.39	5.65	3.15

In a column mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

S₁: *Brassica campestris*

S₂: *Brassica juncea*

S₃: *Brassica napus*

B₀: Control (no biomass application)

B₁: Spreading above the ground

B₂: Mixed with soil

B₃: Spreading in line

B₄: 50% spreading + 50% mixed with soil

The combined effect of *Brassica* sp. and different incorporation methods significantly influenced the shoot length of wheat at different DAS (Appendix VII). At 30 DAS, S₂B₂ (*Brassica juncea* mixed with soil) had the maximum shoot length (30.27 cm) and the minimum shoot length (25.05 cm) was recorded from S₁B₀ (*Brassica campestris* with control). At 50 DAS, S₁B₄ had the maximum shoot length (73.89 cm) and the minimum shoot length (63.45 cm) was recorded from S₂B₃. At 70 DAS, S₁B₂ had the maximum shoot length (91.33 cm) and the minimum shoot length (81.90 cm) was recorded from S₂B₃. At 90 DAS, S₃B₁ had the maximum shoot length (93.12 cm) and the minimum shoot length (82.73 cm) was recorded from S₂B₃ (Table 9).

4.2.5 Spike length

At 70, 90 DAS and harvest spike length of wheat do not differ significantly (Appendix VIII). The *Brassica* species S₁ (*Brassica campestris*) produced the numerically maximum spike length of 9.69 cm, 9.65 cm and 10.91 cm, at 70, 90 DAS and at harvest respectively but at the same period, the minimum spike length (9.43 cm, 9.25 cm and 10.22 cm respectively), was obtained from S₂ (*Brassica juncea*) (Table 10).

Spike length of wheat showed no significant variation by different incorporation methods at 70, 90 DAS and at harvest (Appendix VIII). At 70 DAS, the maximum spike length (9.86 cm) was recorded from B₂ (mixed with soil), while the minimum spike length (9.04 cm) was recorded from B₃ (spreading in line). At 90 DAS, the maximum spike length (9.63 cm) was recorded from B₄ (50% spreading + 50% mixed with soil), while the minimum spike length (8.97 cm) was recorded from B₃. At harvest, the maximum spike length (10.95 cm) was recorded from B₂, while the minimum spike length (10.10 cm) was recorded from B₀ (Table 10).



Table 9. Combined effect of different *Brassica* species and incorporation methods on shoot length at different days after sowing of wheat

Treatment	Shoot length (cm) at			
	30 DAS	50 DAS	70 DAS	90 DAS
S ₁ B ₀	25.05 c	69.10 abc	85.34	86.63 bcde
S ₁ B ₁	26.98 abc	70.22 abc	85.27	86.40 bcde
S ₁ B ₂	28.63 abc	73.79 ab	91.33	91.03 abc
S ₁ B ₃	26.04 abc	63.72 bc	83.53	84.61 de
S ₁ B ₄	27.41 abc	73.89 a	90.60	89.13 abcd
S ₂ B ₀	29.71 ab	69.44 abc	83.67	82.97 e
S ₂ B ₁	26.93 abc	69.10 abc	88.40	89.43 abcd
S ₂ B ₂	30.27 a	70.81 abc	90.50	87.73 bcde
S ₂ B ₃	25.65 bc	63.45 c	81.90	82.73 e
S ₂ B ₄	26.47 abc	68.54 abc	88.07	86.50 bcde
S ₃ B ₀	29.26 abc	70.25 abc	87.37	85.92 cde
S ₃ B ₁	28.13 abc	71.67 abc	89.03	93.12 a
S ₃ B ₂	27.97 abc	72.33 abc	82.87	84.87 de
S ₃ B ₃	26.09 abc	64.95 abc	84.92	94.97 de
S ₃ B ₄	27.49 abc	67.33 abc	90.53	91.60 ab
SE	1.330	2.954	2.834	1.587
CV(%)	8.38	7.39	5.65	3.15

In a column mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

S₁: *Brassica campestris*

S₂: *Brassica juncea*

S₃: *Brassica napus*

B₀: Control (no biomass application)

B₁: Spreading above the ground

B₂: Mixed with soil

B₃: Spreading in line

B₄: 50% spreading + 50% mixed with soil

Table 10. Main effect of different *Brassica* species and incorporation methods on spike length at different days after sowing of wheat

Treatment	Spike length (cm) at		
	70 DAS	90 DAS	Harvest
<i>Brassica</i> species			
S ₁	9.69	9.65	10.91
S ₂	9.43	9.25	10.22
S ₃	9.59	9.38	10.45
SE	0.292	0.342	0.173
Incorporation methods			
B ₀	9.58	9.10	10.10
B ₁	9.65	9.10	10.70
B ₂	9.86	9.52	10.95
B ₃	9.04	8.97	10.21
B ₄	9.73	9.63	10.67
SE	0.309	0.342	0.323
CV(%)	9.68	10.90	9.21

S₁: *Brassica campestris*

S₂: *Brassica juncea*

S₃: *Brassica napus*

B₀: Control (no biomass application)

B₁: Spreading above the ground

B₂: Mixed with soil

B₃: Spreading in line

B₄: 50% spreading + 50% mixed with soil

The combined effect of *Brassica* sp. and different incorporation methods did not significantly influenced the spike length of wheat for 70 and 90 DAS but at harvest it differed significantly (Appendix VIII). At 70 DAS, S₁B₂ (*Brassica campestris* with mixed with soil) had the maximum spike length (10.35 cm) and the minimum spike length (8.57 cm) was recorded from S₂B₃ (*Brassica campestris* with spreading in line). At 90 DAS, S₁B₄ (*Brassica campestris* with spreading in line) had the maximum spike length (10.17 cm) and the minimum spike length (7.77 cm) was recorded from S₁B₂ (*Brassica campestris* with mixed with soil). At harvest, S₁B₂ had the maximum spike length (11.39 cm) and the minimum spike length (9.43 cm) was recorded from S₂B₃ (Table 11).

4.2.6 Root length

Root length differed significantly for 50 DAS and non-significant for 30, 70 and 90 DAS (Appendix IX). At 30 DAS, the S₂ (*Brassica juncea*) produced the maximum root length (9.60 cm) but the minimum root length (9.17 cm) was obtained from S₃ (*Brassica napus*). At 50 DAS, the S₁ produced the maximum root length (12.93 cm) which was statistically similar (12.05) to S₂ but the minimum root length (11.73 cm) was obtained from S₃. At 70 DAS, the S₁ produced the maximum root length (11.70 cm) and but the minimum root length (11.18 cm) was obtained from S₂. At 90 DAS, among the *Brassica* specie S₃ produced the maximum root length (9.59 cm) and the minimum root length (9.37 cm) was obtained from S₁ (Figure 9). Javaid *et al.* (2006) reported that root length was significantly reduced by extracts of all the test crops.

Table 11. Combined effect of different *Brassica* species and incorporation methods on spike length at different days after sowing of wheat

Treatment	Spike length (cm) at		
	70 DAS	90 DAS	Harvest
S ₁ B ₀	9.97	9.49	10.74 ab
S ₁ B ₁	9.17	9.77	10.64 ab
S ₁ B ₂	10.35	7.77	11.39 a
S ₁ B ₃	9.05	9.03	10.43 ab
S ₁ B ₄	9.93	10.17	11.34 ab
S ₂ B ₀	8.66	9.00	10.08 ab
S ₂ B ₁	9.87	9.80	10.77 ab
S ₂ B ₂	10.32	9.83	10.78 ab
S ₂ B ₃	8.57	8.70	9.43 b
S ₂ B ₄	9.75	8.90	10.03 ab
S ₃ B ₀	10.11	8.80	9.47 b
S ₃ B ₁	9.90	10.16	10.70 ab
S ₃ B ₂	8.91	8.95	10.68 ab
S ₃ B ₃	9.51	9.17	10.78 ab
S ₃ B ₄	9.51	9.83	10.65 ab
SE	0.535	0.593	0.560
CV (%)	9.68	10.90	9.21

In a column mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

S₁: *Brassica campestris*

S₂: *Brassica juncea*

S₃: *Brassica napus*

B₀: Control (no biomass application)

B₁: Spreading above the ground

B₂: Mixed with soil

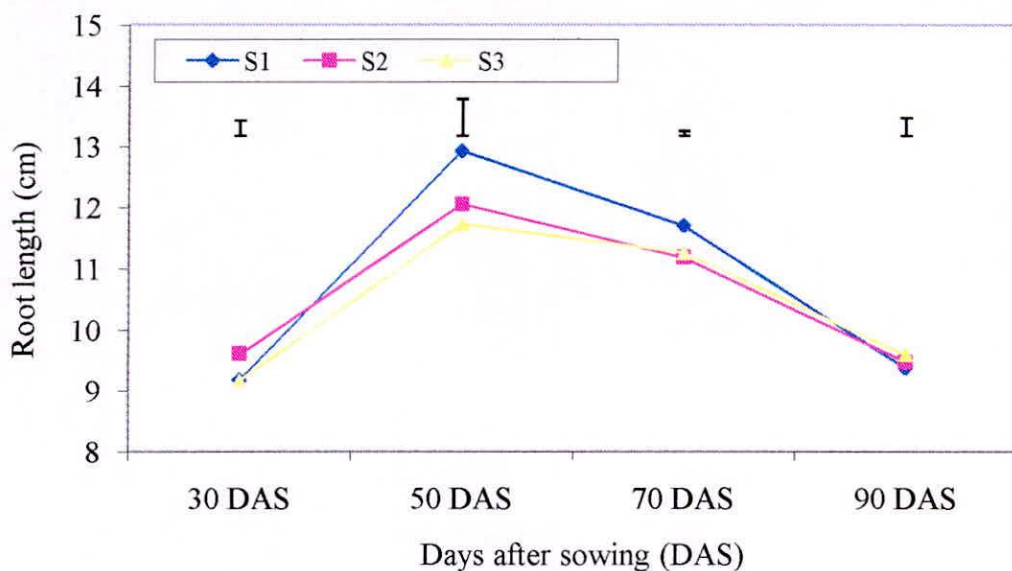
B₃: Spreading in line

B₄: 50% spreading + 50% mixed with soil

Root length of wheat significantly varied by different incorporation methods at 90 DAS but for 30, 50 and 70 DAS it was non-significant (Appendix IX). At 30 DAS, the maximum root length (9.62 cm) was recorded from B₀ (control) whereas the minimum root length (9.05 cm) was recorded from B₁ (spreading above the ground). At 50 DAS, the maximum root length (13.02 cm) was recorded from B₂ (mixed with soil) whereas the minimum root length (11.53 cm) was recorded from B₃. At 70 DAS, the maximum root length (12.09 cm) was recorded from B₄ (50% spreading + 50% mixed with soil) whereas the minimum root length (10.47 cm) was recorded from B₃. At 90 DAS, the highest root length (10.19 cm) was recorded from B₄ (50% spreading + 50% mixed with soil) which was statistically similar (9.66 cm, 9.61 cm and 9.40 cm) to B₀ (control), B₁ (spreading above the ground) and B₃ (spreading in line), respectively, whereas the minimum root length (8.51 cm) was recorded from B₂ (Figure 10). Bhatt and Todaria (1990) reported that root length was depressed by agroforestry tree crops.

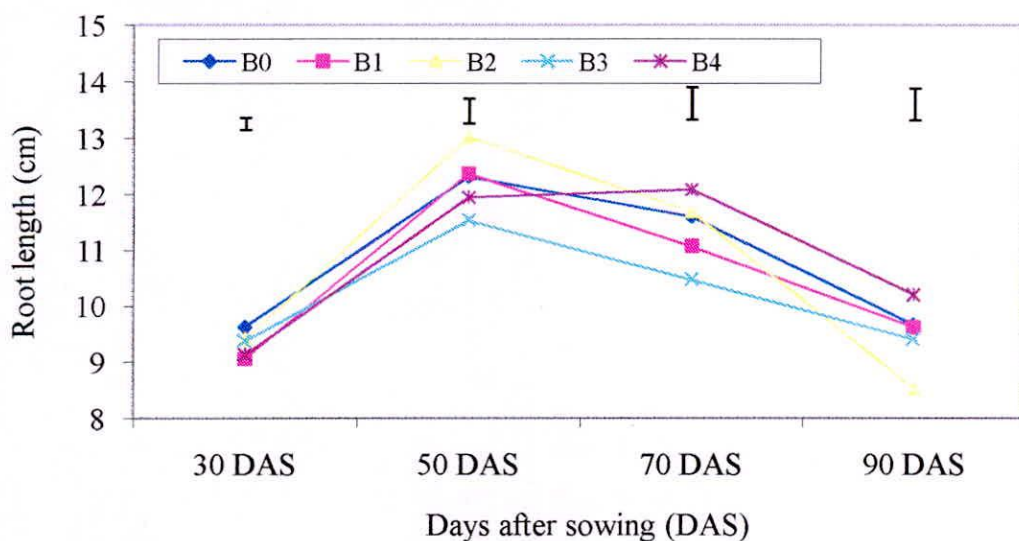
The combined effect of *Brassica* sp. and different incorporation methods significantly influenced the root length of wheat at different DAS (Appendix IX). At 30 DAS, S₂B₀ (*Brassica juncea* with control) had the maximum root length (9.96 cm) and the minimum root length (8.76 cm) was recorded from S₃B₁ (*Brassica napus* with spreading above the ground). At 50 DAS, S₁B₂ (*Brassica campestris* with mixed with soil) had the highest root length (14.46 cm) and the minimum root length (10.65 cm) was recorded from S₃B₃ (*Brassica napus* with spreading in line). At 70 DAS, S₁B₀ (*Brassica campestris* with control) had the maximum root length (12.67 cm) and the minimum root length (9.47 cm) was recorded from S₂B₃ (*Brassica juncea* with spreading in line). At 90 DAS, S₂B₄ (*Brassica juncea* with 50% spreading + 50% mixed with soil) had the highest root length (10.60 cm) and the minimum root length (7.73 cm) was recorded from S₃B₂ (*Brassica napus* with mixed with soil) (Table 12).





S₁: *Brassica campestris*; S₂: *Brassica juncea*; S₃: *Brassica napus*

Figure 9. Effect of different *Brassica* species on root length of wheat. Vertical bars represent the LSD value at $p=0.05$



B₀: Control; B₁: Spreading above the ground; B₂: Mixed with soil
B₃: Spreading in line; B₄: 50% spreading + 50% mixed with soil

Figure 10. Effect of methods of biomass application on root length of wheat. Vertical bars represent the LSD value at $p=0.05$

Table 12. Combined effect of different *Brassica* species and incorporation methods on root length at different days after sowing of wheat

Treatment	Root length (cm) at			
	30 DAS	50 DAS	70 DAS	90 DAS
S ₁ B ₀	9.28	12.58 ab	12.67	9.67 ab
S ₁ B ₁	9.30	12.71 ab	10.63	8.93 ab
S ₁ B ₂	9.00	14.46 a	12.47	8.93 ab
S ₁ B ₃	9.17	12.35 ab	10.73	9.83 ab
S ₁ B ₄	9.14	12.53 ab	12.00	9.47 ab
S ₂ B ₀	9.96	12.21 ab	11.17	9.80 ab
S ₂ B ₁	9.09	12.06 ab	11.50	9.40 ab
S ₂ B ₂	9.87	12.48 ab	11.50	8.87 ab
S ₂ B ₃	9.86	11.60 ab	9.47	8.60 ab
S ₂ B ₄	9.19	11.88 ab	11.97	10.60 a
S ₃ B ₀	9.63	12.17 ab	10.97	9.50 ab
S ₃ B ₁	8.76	12.33 ab	11.03	10.43 a
S ₃ B ₂	9.32	12.13 ab	10.80	7.73 b
S ₃ B ₃	9.08	10.65 b	11.20	9.77 ab
S ₃ B ₄	9.04	11.42 ab	12.31	10.50 a
SE	0.473	0.939	1.163	0.701
CV(%)	8.80	13.30	17.70	12.82

In a column mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

S₁: *Brassica campestris*

S₂: *Brassica juncea*

S₃: *Brassica napus*

B₀: Control (no biomass application)

B₁: Spreading above the ground

B₂: Mixed with soil

B₃: Spreading in line

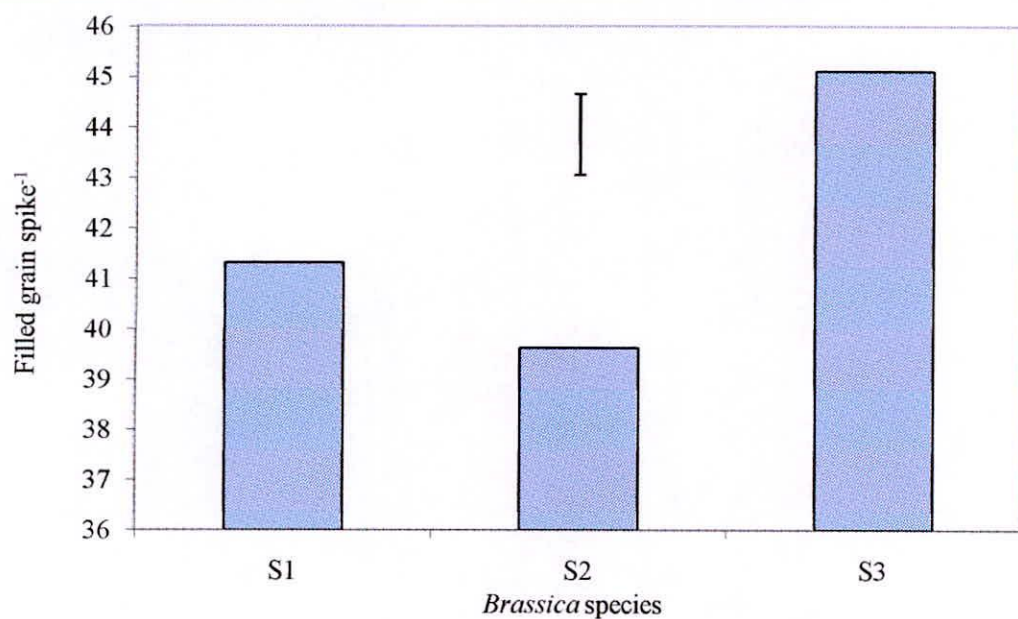
B₄: 50% spreading + 50% mixed with soil

4.2.7 Number of filled grains spike⁻¹

Number of filled grain spike⁻¹ did not differ significantly due to the variation of different *Brassica* species (Appendix X). Among the *Brassica* species *S*₃ (*Brassica napus*) produced the maximum number of filled grain spike⁻¹ (45.12) but the minimum number (39.63) was obtained from *S*₂ (*Brassica juncea*) (Figure 11).

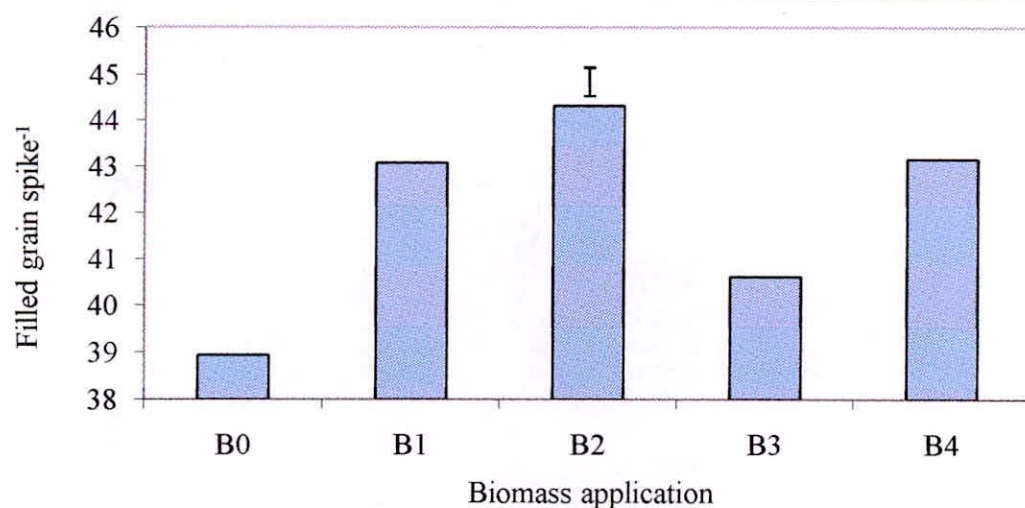
Number of filled grain spike⁻¹ of wheat significantly varied by different incorporation methods of *Brassica* (Appendix X). The maximum number of filled grains spike⁻¹ (44.32) was recorded from *B*₂ (mixed with soil) which was statistically similar (43.16, 43.08 and 40.62) to *B*₄ (50% spreading + 50% mixed with soil), *B*₁ (spreading above the ground) and *B*₃ (spreading in line), respectively, while the minimum number (38.95) was recorded from *B*₀ (control) (Figure 12).

The combined effect of *Brassica* sp. and different incorporation methods significantly influenced the number of filled grains spike⁻¹ of wheat (Appendix X). The *S*₃*B*₄ (*Brassica napus* with 50% spreading + 50% mixed with soil) had the maximum number of filled grains spike⁻¹ (47.24) and the minimum number (35.87) was recorded from *S*₁*B*₃ (*Brassica campestris* with spreading in line) (Figure 13).



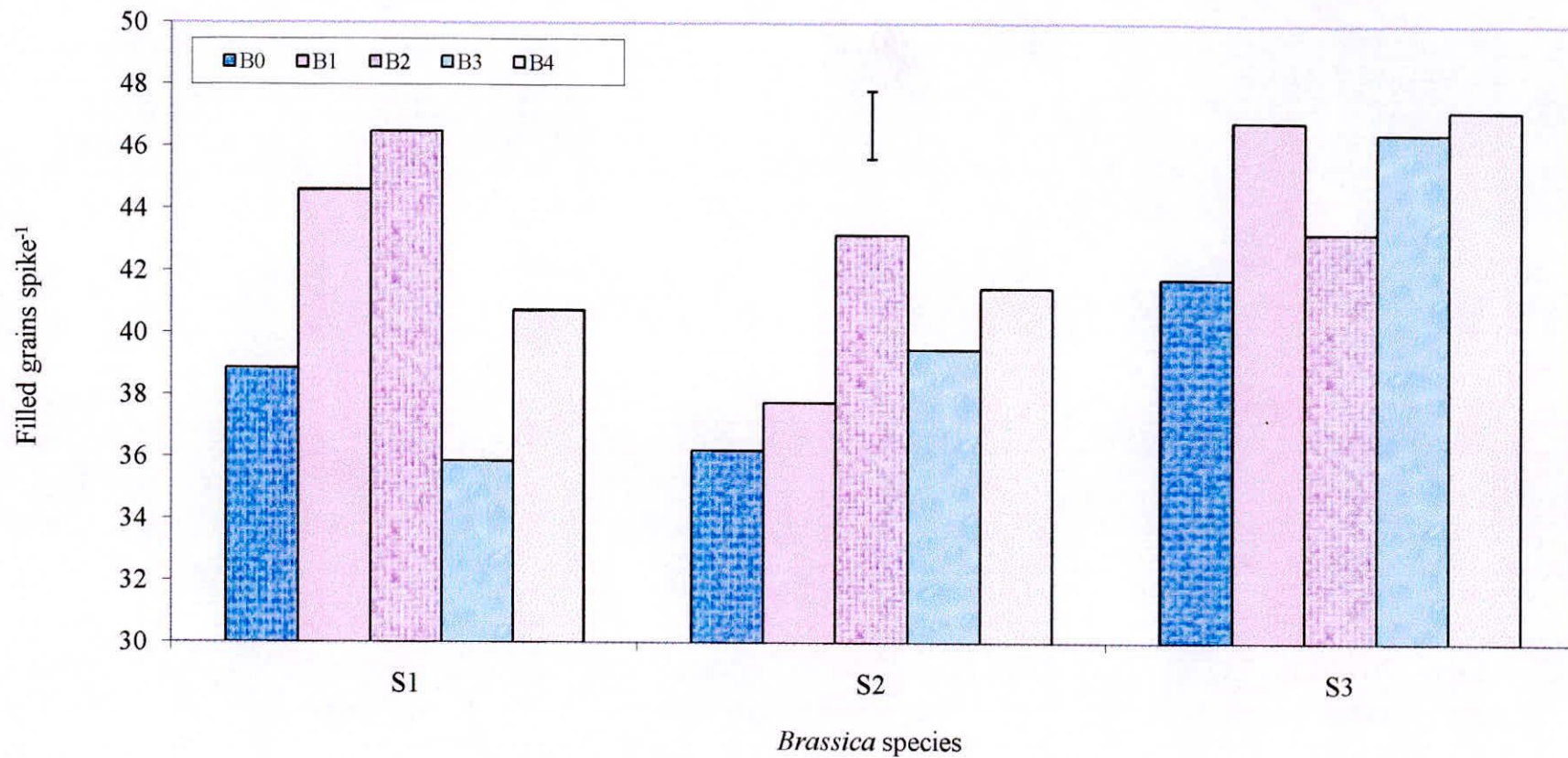
S₁: *Brassica campestris*; S₂: *Brassica juncea*; S₃: *Brassica napus*

Figure 11. Effect of different *Brassica* species on filled grain spike⁻¹ of wheat. Vertical bar represents the LSD value at $p=0.05$



B₀: Control; B₁: Spreading above the ground; B₂: Mixed with soil
B₃: Spreading in line; B₄: 50% spreading + 50% mixed with soil

Figure 12. Effect of methods of biomass application on filled grain spike⁻¹ of wheat. Vertical bar represents the LSD value at $p=0.05$



S₁: *Brassica campestris*; S₂: *Brassica juncea*; S₃: *Brassica napus*

B₀: Control; B₁: Spreading above the ground; B₂: Mixed with soil

B₃: Spreading in line; B₄: 50% spreading + 50% mixed with soil

Figure 13. Effect of *Brassica* species and methods of biomass application on filled grains spike⁻¹ in wheat.
Vertical bar represents the LSD value at p=0.05

4.2.8 Number of unfilled grains spike⁻¹

Number of unfilled grains spike⁻¹ did not differ significantly due to the application of different *Brassica* species (Appendix X). Among the *Brassica* species S₁ (*Brassica campestris*) produced the maximum number of unfilled grain spike⁻¹ (1.90) but the minimum number (1.45) was obtained from S₃ (*Brassica napus*) (Table 13).

Number of unfilled grains spike⁻¹ of wheat was significantly varied for different incorporation methods of *Brassica* (Appendix X). The maximum number of unfilled grains spike⁻¹ (1.77) was recorded from B₁ (spreading above the ground) which was statistically similar (1.70 and 1.56) to B₃ (spreading in line), B₀ (control) and B₄ (50% spreading + 50% mixed with soil), respectively, while the minimum number (1.48) was recorded from B₂ (Table 13).

The combined effect of *Brassica* sp. and different incorporation methods significantly influenced the number of unfilled grains spike⁻¹ of wheat (Appendix X). The S₁B₃ (*Brassica campestris* with spreading in line) had the maximum number of unfilled grains spike⁻¹ (2.20) and the minimum number (1.32) was recorded from S₂B₂ (*Brassica juncea* with mixed with soil) (Table 14).

4.2.9 Percentage of filled grain

Percentage of filled grains did not differ significantly due to the application of different *Brassica* species (Appendix X). Among the *Brassica* species S₃ (*Brassica napus*) produced the maximum percentage of filled grain (96.85%) but the minimum (95.47%) was obtained from S₁ (*Brassica campestris*). On the other hand S₂ produced 96.13% percentage of filled grain (Table 13).

Percentage of filled grains varied significantly due to different incorporation methods of *Brassica* (Appendix X). The highest percentage of filled grains (96.74%) was recorded from B₂ (mixed with soil) which was statistically similar (96.48%) to B₄ (50% spreading + 50% mixed with soil), while the lowest (95.77%) was recorded from B₀ (Table 13).

The combined effect of *Brassica* sp. and different incorporation methods significantly influenced the percent filled grain of wheat (Appendix X). The S₃B₁ (*Brassica napus* with spreading above the ground) had the highest percentage of filled grain (97.11%) and the lowest (94.09%) was recorded from S₁B₃ (*Brassica campestris* with spreading in line) (Table 14).

4.2.10 1000 grain weight

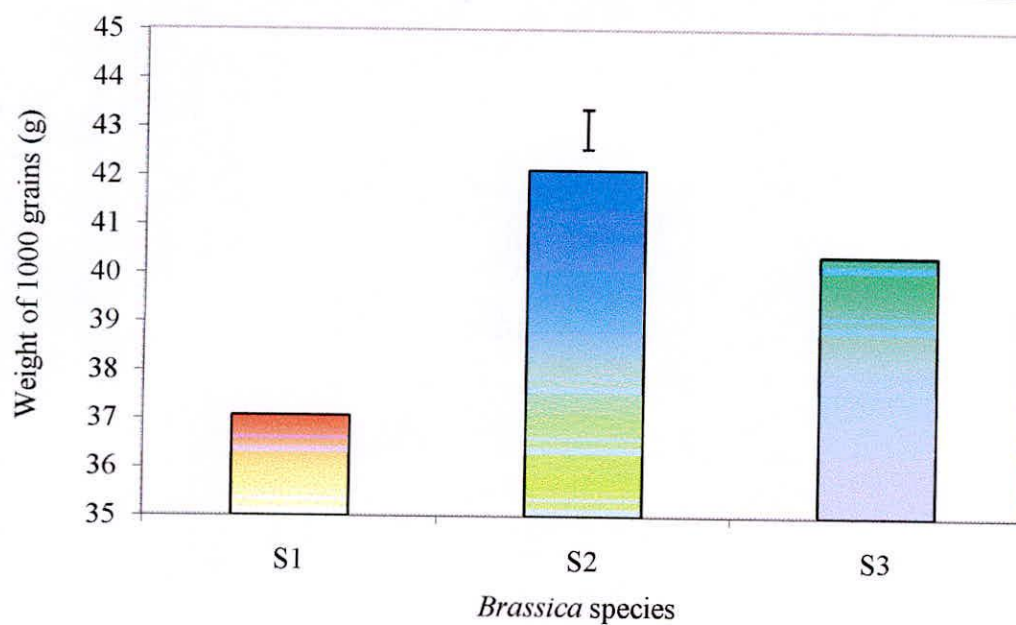
The 1000 grain weight differed significantly due to the variation of different *Brassica* species (Appendix X). Among the *Brassica* species S₂ (*Brassica juncea*) produced the highest 1000 grain weight (42.13 g) which was statistically similar (40.38 g) to S₃ (*Brassica napus*) and the lowest (37.07 g) was obtained from S₁ (*Brassica campestris*) (Figure 14).

The 1000 grain weight varied significantly due to different incorporation methods of *Brassica* (Appendix X). The highest 1000 grain weight (43.63 g) was recorded from B₂ (mixed with soil) while the lowest (37.18 g) was recorded from B₃ which was statistically similar (38.30 g) to B₄ (50% spreading + 50% mixed with soil) (Figure 15).

The combined effect of *Brassica* sp. and different incorporation methods significantly influenced the 1000 grain weight of wheat (Appendix X). The S₂B₂ (*Brassica juncea* with mixed with soil) had the highest 1000 grain weight (48.77 g) and the lowest (33.09 g) was recorded from S₁B₃ (*Brassica campestris* with spreading in line) (Figure 16).

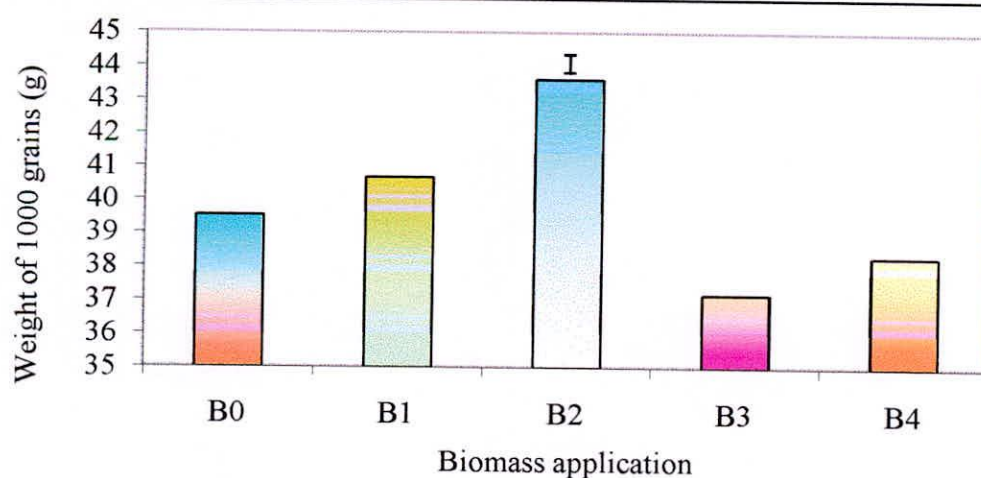
4.2.11 Grain yield

The grain yield did not differed significantly due to the variation of different *Brassica* species (Appendix XI). Among the *Brassica* species S₂ (*Brassica juncea*) produced the numerically maximum grain yield (3.52 t ha⁻¹) and the minimum (3.32 t ha⁻¹) was obtained from S₃ (*Brassica napus*). On the other hand, S₁ (*Brassica campestris*) produced intermediate grain yield (3.43 t ha⁻¹) (Table 13).



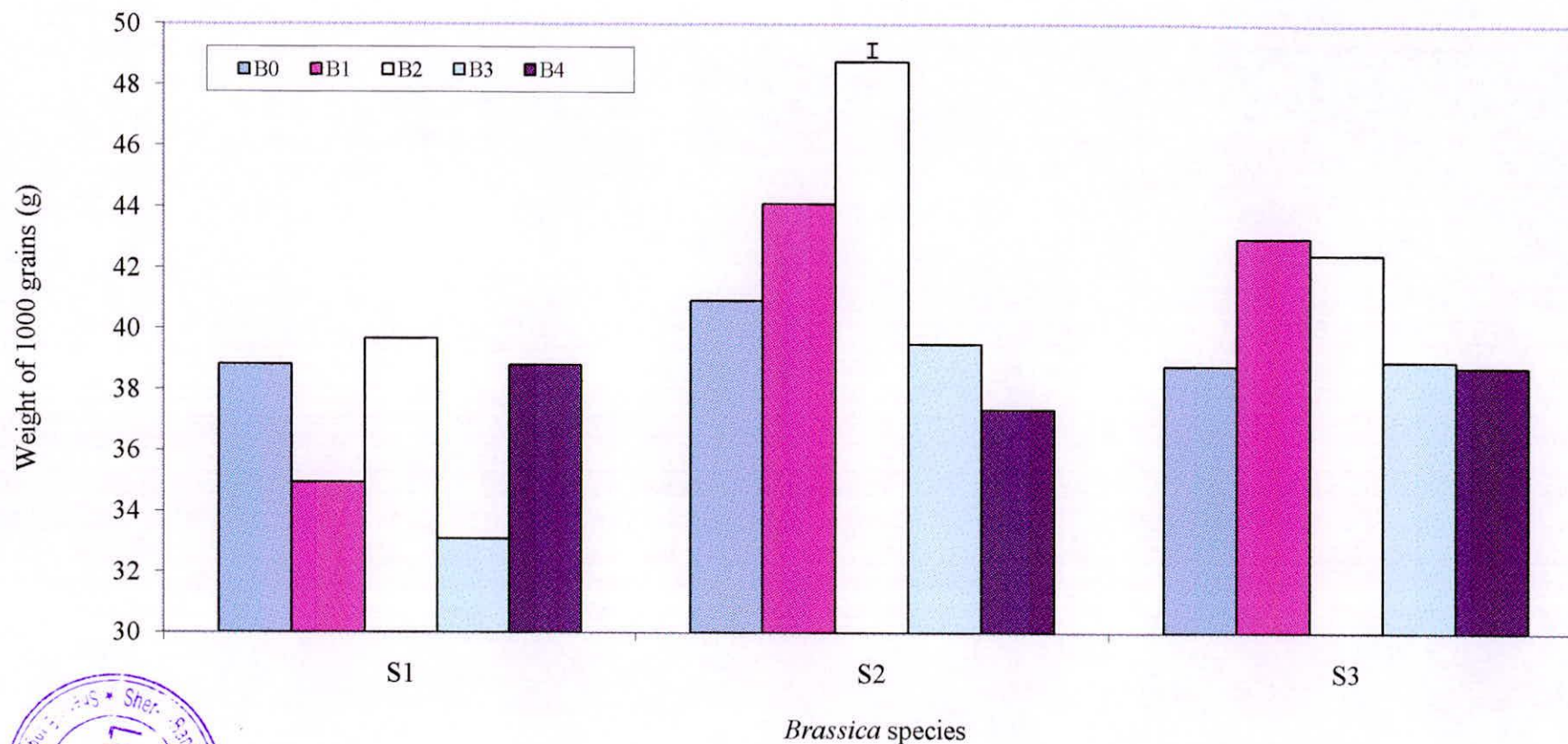
S₁: *Brassica campestris*; S₂: *Brassica juncea*; S₃: *Brassica napus*

Figure 14. Effect of different *Brassica* species on weight of 1000 grains of wheat. Vertical bar represents the LSD value at $p=0.05$



B₀: Control; B₁: Spreading above the ground; B₂: Mixed with soil
B₃: Spreading in line B₄: 50% spreading + 50% mixed with soil

Figure 15. Effect of methods of biomass application on weight of 1000 grains of wheat. Vertical bar represents the LSD value at $p=0.05$



S₁: *Brassica campestris*; S₂: *Brassica juncea*; S₃: *Brassica napus*

B₀: Control; B₁: Spreading above the ground; B₂: Mixed with soil
 B₃: Spreading in line B₄: 50% spreading + 50% mixed with soil

Figure 16. Effect of *Brassica* species and methods of biomass application on weight of 1000 grains of wheat.
 Vertical bar represents the LSD value at $p=0.05$

The grain yield varied non-significantly due to different incorporation methods of *Brassica* (Appendix XI). The maximum grain yield (3.54 t ha^{-1}) was recorded from B_0 (control) while the minimum (3.32 t ha^{-1}) was recorded from B_2 (mixed with soil) (Table 13). Barker and Bhowmik (2001) reported that 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.

The combined effect of *Brassica* sp. and different incorporation methods significantly influenced the grain yield of wheat (Appendix XI). The S_2B_1 (*Brassica juncea* with spreading above the ground) had the highest grain yield (3.83 t ha^{-1}) and the lowest (3.06 t ha^{-1}) was recorded from S_3B_1 (*Brassica napus* with spreading above the ground) (Table 14).

4.2.12 Straw yield

The straw yield did not differ significantly due to the variation of different *Brassica* species (Appendix XI). Among the *Brassica* species S_2 (*Brassica juncea*) produced the maximum straw yield (3.84 t ha^{-1}) and the minimum (3.64 t ha^{-1}) was obtained from S_1 (*Brassica campestris*). On the other hand, S_3 (*Brassica napus*) produced straw yield (3.73 t ha^{-1}) (Table 13).

Straw yield varied non-significantly due to different incorporation methods of *Brassica* (Appendix XI). The maximum straw yield (3.85 t ha^{-1}) was recorded from B_0 (control) while the minimum (3.56 t ha^{-1}) was recorded from B_4 (50% spreading + 50% mixed with soil) (Table 13).

The combined effect of *Brassica* sp. and different incorporation methods significantly influenced the straw yield of wheat (Appendix XI). The S_3B_0 (*Brassica napus* with control) had the highest straw yield (4.27 t ha^{-1}) and the lowest (3.40 t ha^{-1}) was recorded from S_3B_1 (*Brassica napus* with spreading above the ground) (Table 14).

4.2.13 Harvest index

The harvest index did not differ significantly due to the variation of different *Brassica* species (Appendix XI). Among the *Brassica* species S_1 (*Brassica campestris*) produced the maximum harvest index (48.47%) but the minimum (47.27%) was obtained from S_3 (*Brassica napus*). On the other hand S_2 gave 47.60% harvest index (Table 13).

The harvest index varied significantly due to different incorporation methods of *Brassica* (Appendix XI). The highest harvest index (49.00%) was recorded from B_4 (50% spreading + 50% mixed with soil) which was statistically similar (48.11% and 47.78%) to B_1 (spreading above the ground), B_0 (control), B_3 (spreading in line), while the minimum (46.22%) was recorded from B_2 (Table 13).

The combined effect of *Brassica* sp. and different incorporation methods significantly influenced the harvest index of wheat (Appendix XI). The S_2B_4 (*Brassica juncea* with 50% spreading + 50% mixed with soil) had the highest harvest index (51.67%) and the lowest (46.00%) was recorded from S_1B_2 (*Brassica campestris* spreading above the ground) (Table 14).

Table 13. Main effect of different *Brassica* species and incorporation methods on yield contributing characters and yield of wheat

Treatment	Unfilled grains spike ⁻¹	Filled grains (%)	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Harvest index (%)
<i>Brassica</i> species					
S ₁	1.90	95.47	3.43	3.64	48.47
S ₂	1.57	96.13	3.52	3.84	47.60
S ₃	1.45	96.85	3.32	3.73	47.27
SE	0.167	1.474	0.085	0.084	0.006
Incorporation methods					
B ₀	1.70 ab	95.77 c	3.54	3.85	47.78 ab
B ₁	1.77 a	95.94 bc	3.45	3.76	48.11 ab
B ₂	1.48 b	96.74 a	3.32	3.84	46.22 b
B ₃	1.70 ab	95.84 bc	3.37	3.66	47.78 ab
B ₄	1.56 ab	96.48 ab	3.43	3.56	49.00 a
SE	0.167	1.196	0.121	0.145	0.006
CV(%)	14.00	0.68	10.61	11.64	4.00

In a column mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

S₁: *Brassica campestris*

S₂: *Brassica juncea*

S₃: *Brassica napus*

B₀: Control (no biomass application)

B₁: Spreading above the ground

B₂: Mixed with soil

B₃: Spreading in line

B₄: 50% spreading + 50% mixed with soil

Table 14. Combined effect of different *Brassica* species and incorporation methods on yield contributing characters and yield of wheat

Treatment	Unfilled grains spike ⁻¹	Filled grains (%)	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Harvest index (%)
S ₁ B ₀	1.88 abc	95.37 c	3.61 ab	3.44 ab	51.00 a
S ₁ B ₁	2.10 ab	95.39 c	3.50 ab	3.72 ab	48.67 ab
S ₁ B ₂	1.67 cd	96.47 abc	3.39 ab	3.95 ab	46.00 b
S ₁ B ₃	2.20 a	94.09 d	3.39 ab	3.64 ab	48.00 ab
S ₁ B ₄	1.67 cd	96.05 abc	3.28 ab	3.44 ab	48.67 ab
S ₂ B ₀	1.67 cd	95.59 bc	3.33 ab	3.83 ab	46.33 b
S ₂ B ₁	1.88 abc	95.23 c	3.83 a	4.17 ab	47.67 ab
S ₂ B ₂	1.32 d	96.98 a	3.33 ab	3.89 ab	46.00 b
S ₂ B ₃	1.44 cd	96.48 abc	3.34 ab	3.69 ab	47.33 ab
S ₂ B ₄	1.56 cd	96.37 abc	3.75 ab	3.61 ab	51.67 a
S ₃ B ₀	1.56 cd	96.36 abc	3.67 ab	4.27 a	46.00 b
S ₃ B ₁	1.33 d	97.11 a	3.06 b	3.40 b	48.00 ab
S ₃ B ₂	1.45 cd	96.76 ab	3.23 ab	3.70 ab	46.67 b
S ₃ B ₃	1.44 cd	96.96 a	3.38 ab	3.66 ab	48.00 ab
S ₃ B ₄	1.44 cd	97.04 a	3.28 ab	3.61 ab	47.67 ab
SE	0.077	2.072	0.210	0.251	0.011
CV(%)	14.00	0.68	10.61	11.64	4.00

In a column mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

S₁: *Brassica campestris*

S₂: *Brassica juncea*

S₃: *Brassica napus*

B₀: Control (no biomass application)

B₁: Spreading above the ground

B₂: Mixed with soil

B₃: Spreading in line

B₄: 50% spreading + 50% mixed with soil

CHAPTER 5

SUMMARY AND CONCLUSION

The experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2007 to February 2008 to study the allelopathic effects of Brassica biomass to control weeds and yield of wheat. The experiment considered as two factors. Factor A (Main plot): 3 levels of *Brassica* Species viz. S_1 : *Brassica campestris*, S_2 : *Brassica juncea* and S_3 : *Brassica napus*; Factor B (sub plot): 5 levels of incorporation methods *Brassica* biomass viz. B_0 : Control (no biomass application); B_1 : Spreading above the ground; B_2 : Mixed with soil; B_3 : Spreading in line and B_4 : 50% spreading + 50% mixed with soil. The experiment was laid out in split-plot design with three replications.

The results of the weed parameters, crop characters which were influenced by different treatment to control weeds by different methods of incorporation have been recorded. Different weed species (12) belonging to 7 families were found infested in the experimental field. *Cyperous rotundus*, *Cynodon dactylon*, *Eleusine indica*, *Digitaria sanguinalis*, *Chenopodium album* were found with major population among the 12 weed species. *Brassica* species affected on weed population. At 30 DAS, the maximum numbers of weeds (25.53 m^{-2}) were found in the plot treated with *Brassica juncea* which was 44.81% higher than the least number of weed population (17.67 m^{-2}) from *Brassica campestris*. At 50 DAS, *Brassica juncea* also showed the highest weed population (20.20 m^{-2}). *Brassica campestris* had the best effect on weed control as there had the least number of weed population (14.07 m^{-2}). At 30 DAS, the lowest weed population (15.33 m^{-2}) was seen by B_3 and the highest weed population (26.89 m^{-2}) was found in the B_2 . At 50 DAS, the highest (20.89 m^{-2}) weed population was found by B_2 whereas B_4 showed the lowest (13.11 m^{-2}) population. At 30 DAS the maximum (37.33 m^{-2}) weed population was observed in S_2B_0 but at 50 DAS, S_3B_2 treatment showed the maximum (40.00 m^{-2}) weed population whereas S_1B_2 showed the lowest (8.67 m^{-2}) weed population.

At 30 DAS S_2 produced the tallest plant (26.62 cm) among the species whereas S_1 (*Brassica campestris*) produced the tallest (67.85 cm, 83.29 cm and 85.15 cm) plant at 50, 70 and 90 DAS. The shortest plant (25.73) was observed from S_1 at 30 DAS but at 50, 70, 90 DAS the shortest plant (66.03 cm, 82.37 cm and 82.53 cm) was observed from S_2 . At 70, 90 DAS and at harvest among the *Brassica* species S_1 produced the maximum spike length (9.69 cm, 9.65 cm and 10.91 cm, respectively) but at the same period, the minimum spike length (9.43 cm, 9.25 cm and 10.22 cm, respectively) was obtained from S_2 . Among the *Brassica* specie S_3 produced the highest percentage of filled grain (96.85%) but the lowest (95.47%) was obtained from S_1 . The S_2 produced the highest 1000 grain weight (42.13 g) and the lowest (37.07 g) was obtained from S_1 . Among the *Brassica* species S_2 produced the highest grain yield (3.52 t ha^{-1}) and the lowest (3.32 t ha^{-1}) was obtained from S_3 . The S_2 produced the highest straw yield (3.84 t ha^{-1}) and the lowest (3.64 t ha^{-1}) was obtained from S_1 .

At 30 and 50 DAS, the tallest plant (27.92 cm, 69.98 cm respectively) was recorded from B_2 , at 70 DAS, the tallest plant (85.61 cm) was recorded from B_4 at 90 DAS, the tallest plant (86.08 cm) was recorded from B_1 . On the other hand, B_3 produced the shortest plant at 30 DAS (24.62 cm), 50 DAS (62.39 cm), 70 DAS (79.60 cm) and 90 DAS (79.69 cm). At 70 DAS, the maximum spike length (9.86 cm) was recorded from B_2 , while the minimum spike length (9.04 cm) was recorded from B_3 . At 90 DAS, the maximum spike length (9.63 cm) was recorded from B_4 , while the minimum spike length (8.97 cm) was recorded from B_3 . At harvest, the maximum spike length (10.95 cm) was recorded from B_2 , while the minimum spike length (10.10 cm) was recorded from B_0 . The highest percentage of filled grains (96.74%) was recorded from B_2 , while the lowest (95.77%) was recorded from B_0 . The highest 1000 grain weight (43.63 g) was recorded from B_2 while the lowest (37.18 g) was recorded from B_3 . The highest grain yield (3.54 t ha^{-1}) was recorded from B_0 while the lowest (3.32 t ha^{-1}) was recorded from B_2 . The highest straw yield (3.85 t ha^{-1}) was recorded from B_0 while the lowest (3.56 t ha^{-1}) was recorded from B_4 .



At 30 DAS, S₂B₂ showed the tallest plant (29.07 cm) whereas S₁B₀ showed the shortest plant (24.14 cm). At 50 DAS, S₁B₄ had the tallest plant (71.48 cm). At 70 DAS, S₁B₂ produced the tallest plant (87.27 cm) and S₂B₃ produced the shortest plant (77.87 cm). The S₃B₁ had the tallest plant (89.33 cm) and S₃B₃ had the shortest plant (79.13 cm) at 90 DAS. At 70 DAS, S₁B₂ had the maximum spike length (10.35 cm) and the minimum spike length (8.57 cm) was recorded from S₂B₃. At 90 DAS, S₁B₄ had the maximum spike length (10.17 cm) and the minimum spike length (7.77 cm) was recorded from S₁B₂. At harvest, S₁B₂ had the maximum spike length (11.39 cm) and the minimum spike length (9.43 cm) was recorded from S₂B₃. The S₂B₂ had the highest 1000 grain weight (48.77 g) and the lowest (33.09 g) was recorded from S₁B₃. The S₂B₁ had the highest grain yield (3.83 t ha⁻¹) and the lowest (3.06 t ha⁻¹) was recorded from S₃B₁. The S₃B₀ had the highest straw yield (4.27 t ha⁻¹) and the lowest (3.40 t ha⁻¹) was recorded from S₃B₁.

Considering the results of the present experiment, we can conclude that among the *Brassica* species *Brassica campestris* had been most effective but rest two had also shown effectiveness in controlling weed. On the other hand, B₄ (50% spreading + 50%, mixed with soil) was the best incorporation method to control weed. But both the effect of species and incorporation method had no remarkable affect in yield. Further studies may be carried out in different agro-ecological zones (AEZ) of Bangladesh for regional compliance including more management practices to achieve maximum yield of wheat.

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APPENDICES

Appendix I. Monthly record of air temperature, relative humidity, rainfall and sunshine hour of the experimental site during the period from October 2007 to February 2008

Month	*Air temperature ($^{\circ}$ C)		*Relative humidity (%)	*Rain fall (mm) (total)	*Sunshine (hr)
	Maximum	Minimum			
October, 2007	29.18	18.26	81	39	7.4
November, 2007	25.82	16.04	78	00	8.1
December, 2007	22.4	13.5	74	00	6.3
January, 2008	24.5	12.4	68	00	5.7
February, 2008	27.1	16.7	67	30	6.7

* Monthly average,

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka - 1212

Appendix II. Characteristics of Agronomy Farm soil as analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy Farm Field , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level

B. Physical properties of the experimental field

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	silty-clay

Source: SRDI

C. Chemical properties of the experimental field

Characteristics	Before sowing <i>Brassica</i>	After harvesting <i>Brassica</i>	After harvesting wheat
pH	6.9	6.8	5.7
OM %	1.21	1.44	1.41
Total N %	0.06	0.067	0.07
P (ppm)	4.5	8.3	11.8
K	0.21	0.20	0.23

Appendix III. Analysis of variance of the data on weed population m^{-1} and dry weight of weed biomass as influenced *Brassica* species and process of biomass application

Source of variation	Degrees of freedom	Mean square			
		Weed population (No. m^{-2}) at		Dry weight of weed biomass (gm^2)	
		30 DAS	50 DAS	30 DAS	50 DAS
Replication	2	218.689	571.356	2.1236	0.2317
<i>Brassica</i> species (A)	2	235.822	154.956	1.57928	0.04224
Error	4	73.156	143.756	73.4889	143.756
Biomass application (B)	4	248.611	86.300	0.98929	0.946515
Interaction (A×B)	8	133.128	261.567	0.73929	0.25436
Error	24	93.139	174.344	93.8389	174.344

Appendix IV. Analysis of variance of the data on plant height of wheat as influenced *Brassica* species and process of biomass application

Source of variation	Degrees of freedom	Mean square			
		Plant height (cm) at			
		30 DAS	50 DAS	70 DAS	90 DAS
Replication	2	7.195	7.582	18.182	2.147
<i>Brassica</i> species (A)	2	3.467	14.460	3.193	13.511
Error	4	30.127	14.474	10.954	3.137
Biomass application (B)	4	13.734*	72.002*	51.323	62.984**
Interaction (A×B)	8	4.889	8.986	23.173	19.911**
Error	24	4.857	23.315	22.538	6.082

** : Significant at 0.01 level of probability;

* : Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data on number of tillers m^{-2} of wheat as influenced *Brassica* species and process of biomass application

Source of variation	Degrees of freedom	Mean square			
		Number of tillers m^{-2} at			
		30 DAS	50 DAS	70 DAS	90 DAS
Replication	2	405.95	854.29	1449.60	2420.27
<i>Brassica</i> species (A)	2	605.42	427.62	929.07	17.067
Error	4	429.96	709.16	140.27	198.933
Biomass application (B)	4	440.58	1014.98	152.36	98.311
Interaction (A×B)	8	264.98	335.09	239.29	118.84
Error	24	324.84	556.75	280.71	142.93

Appendix VI. Analysis of variance of the data on number of effective tillers m^{-2} of wheat as influenced *Brassica* species and process of biomass application

Source of variation	Degrees of freedom	Mean square		
		Number of effective tillers m^{-2} at		
		70 DAS	90 DAS	Harvest
Replication	2	2681.96	1039.02	1033.36
<i>Brassica</i> species (A)	2	240.35	42.222	33.089
Error	4	71.822	452.09	360.96
Biomass application (B)	4	180.44	113.69	100.47
Interaction (A×B)	8	393.24	173.56	133.03
Error	24	164.98	203.07	171.31

Appendix VII. Analysis of variance of the data on shoot length of wheat as influenced *Brassica* species and process of biomass application

Source of variation	Degrees of freedom	Mean square			
		Shoot length (cm) at			
		30 DAS	50 DAS	70 DAS	90 DAS
Replication	2	5.490	5.699	21.827	1.872
<i>Brassica</i> species (A)	2	4.774	13.248	1.914	20.178*
Error	4	31.688	14.597	10.852	2.145
Biomass application (B)	4	11.266	86.102*	54.504	53.281**
Interaction (A×B)	8	5.450	9.465	24.755	19.385*
Error	24	5.303	26.175	24.086	7.554

** : Significant at 0.01 level of probability:

* : Significant at 0.05 level of probability

Appendix VIII. Analysis of variance of the data on spike length as influenced *Brassica* species and process of biomass application

Source of variation	Degrees of freedom	Mean square		
		Spike length (cm) at		
		70 DAS	90 DAS	Harvest
Replication	2	0.995	1.149	0.262
<i>Brassica</i> species (A)	2	0.259	0.617	1.845
Error	4	1.275	1.755	0.447
Biomass application (B)	4	0.888	1.357	1.158
Interaction (A×B)	8	1.245	0.527	0.643
Error	24	0.859	1.055	0.940



Appendix IX. Analysis of variance of the data on root length of wheat as influenced *Brassica* species and process of biomass application

Source of variation	Degrees of freedom	Mean square			
		Root length (cm) at			
		30 DAS	50 DAS	70 DAS	90 DAS
Replication	2	1.165	5.273	11.592	3.794
<i>Brassica</i> species (A)	2	0.899	5.745	1.171	0.182
Error	4	1.929	1.318	7.165	0.940
Biomass application (B)	4	0.478	2.768	3.582	3.365
Interaction (A×B)	8	0.206	0.666	1.654	1.402
Error	24	0.672	2.647	4.056	1.474

Appendix X. Analysis of variance of the data on yield contributing characters of wheat as influenced *Brassica* species and process of biomass application

Source of variation	Degrees of freedom	Mean square			
		Filled grain spike ⁻¹ No.)	Unfilled grain spike ⁻¹	Filled grain (%)	1000 grain weight (g)
Replication	2	14.109	0.072	0.717	23.444
<i>Brassica</i> species (A)	2	118.595	0.837	7.064	99.165*
Error	4	32.610	0.416	3.676	8.087
Biomass application (B)	4	42.917*	0.129	1.698*	55.431*
Interaction (A×B)	8	27.006	0.103	1.272*	21.337
Error	24	12.874	0.053	0.433	15.173

**: Significant at 0.01 level of probability;

*: Significant at 0.05 level of probability

Appendix XI. Analysis of variance of the data on yield of wheat and harvest index of wheat as influenced *Brassica* species and process of biomass application

Source of variation	Degrees of freedom	Mean square		
		Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Harvest index (%)
Replication	2	0.263	0.243	0.0001
<i>Brassica</i> species (A)	2	0.140	0.151	0.001
Error	4	0.109	0.105	0.0001
Biomass application (B)	4	0.065	0.142	0.001
Interaction (A×B)	8	0.160	0.222	0.001
Error	24	0.132	0.189	0.0001

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