SCREENING OF ALLELOPATHIC POTENTIAL BANGLADESH WHEAT (*Triticum aestivum* L.) VARIETIES

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Dedicated to
My
Beloved Parents

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CERTIFICATE

This is to certify that the thesis entitled ***"SCREENING OF ALLELOPATHIC POTENTIAL BANGLADESH WHEAT (Triticum aestivum L.) VARIETIES"*** *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 (MS) in AGRONOMY,*** *embodies the results of a piece of bona fide research work carried out by* ***MD. TOUHIDUL ALAM SHOHAN, Registration. No. 13-05546*** *under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

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

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SCREENING OF ALLELOPATHIC POTENTIAL BANGLADESH WHEAT (*Triticum aestivum* L.) VARIETIES

ABSTRACT

A series of experiments were carried out in the laboratory and agronomy field of the Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, from September 2018 to March 2019 to screen out the allelopathic potential Bangladesh wheat varieties (*Triticum aestivum* L.). The experimental design in laboratory bioassay was a completely randomized design (CRD) with four replications and a randomized complete block design (RCBD) with three replications in the field experiment. Initially, the donor-receiver bioassay method was used to assess allelopathic potential varieties in laboratory (*in-vitro*) conditions. *Raphanus sativus* (radish) and *Lactuca sativa* (lettuce) as model receiver plants, *Chenopodium album* (common lambs' quarter), and *Amaranthus viridis* (pigweed) as test receiver weeds were used for the screening test. BARI Gom 21 gave the highest inhibition effect (81%) on *C. album* root while the stimulating effect was given by BARI Gom 30 (-48.2%) on *R. sativus* root. BARI Gom 21 also reduced the speed of germination against *R. sativus, L. sativa, C. album,* and *A. viridis* (5.35, 4, 4.32 and 5.83 respectively) as well as the coefficient of the velocity of germination of *A. viridis* was 1.92. Eleven wheat varieties were selected including allelopathic and non-allelopathic from the laboratory test for the field study which was raised by following no weed control method. The growth pattern of infesting major weeds concerning wheat grown for grain in wheat fields was also observed. There were different weed species under nine different flora families viz., *Cynodon dactylon, Eleusine indica, Echinochloa colona, Cyperus rotundus, C. album, A. viridis, A. spinosus, Heliotropium indicum, Alternanthera philoxeroides, Corchorus acutangulus, Vicia sativa, Solanum caroliensis, S. torvum, Lindernia procumbens,* etc. which infested experimental plots. BARI Gom 21 raised plots had the lowest infestation and the lowest dry matter of weeds (12 g) resulting in maximum weed control efficiency (87%). In addition, several weed species including *C. album and A. viridis* were not grown in the BARI Gom 21 variety raised plots. The strong allelopathic inhibition of this variety on the seed germination and seedling growth of wheat may be the important reason for these weeds' repulsion in the wheat field. BARI Gom 21 reduced the weed density (14.66 m^{-2}, 28.33 m^{-2} and 33.33 m^{-2} at 15, 25 and 35 DAS respectively). The Simpson Diversity Index (SDI) was calculated against different varieties, and the highest in BARI Gom 21 (0.82) and the lowest in BARI Gom 22 (0.68). There found a positive correlation (R^2 = 0.386) between SDI and the root inhibition percentage of laboratory bioassay. Therefore, BARI Gom 21 wheat variety was selected as the most allelopathic among the tested Bangladesh wheat variety. This wheat variety could be used for the isolation and identification of allelochemicals and to develop by breeding and adopting other agronomic practices for obtaining optimum yield performance and tolerance to weeds, and in particular, to achieve improved biological weed control for the sustainable production of wheat.

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LIST OF ABBREVIATIONS

AEZ	=	Agro-Ecological Zone
BADC	=	Bangladesh Agricultural Development Corporation
BARI	=	Bangladesh Agricultural Research Institute
BAW	=	Bangladesh Agricultural University
cm	=	Centimeter
CV%	=	Percentage of coefficient of variation
cv.	=	Cultivar
DAS	=	Days after sowing
ECAM	=	Equal Compartment Agar Method
et al.	=	And others
FAO	=	Food and Agriculture Organization
G	=	Gram (g)
ha^{-1}	=	Per hectare
HI	=	Harvest Index
Hr	=	Hour
kg	=	Kilogram
LSD	=	Least Significant Difference
Max	=	Maximum
mg	=	Milligram
Min	=	Minimum
mL	=	Milli litre
N	=	Nitrogen
No.	=	Number
NPK	=	Nitrogen, Phosphorus and Potassium
NS	=	Non significant
ppm	=	Parts per million
SAU	=	Sher-e-Bangla Agricultural University
SDI	=	Simpson’s Diversity Index
SOD	=	Superoxide dismutase
SRDI	=	Soil Resources and Development Institute

T	=	Ton
t ha^{-1}	=	Ton per hactre
viz.	=	Videlicet (namely)
WCE	=	Weed Control Efficiency
WRC	=	Wheat Research Center
WSL	=	Wheat Straw Leachate
Wt.	=	Weight
%	=	Percent
µg	=	Micro gram
^0C	=	Degree Celsius

CHAPTER 1

INTRODUCTION

Wheat (*Triticum aestivum* L.) is among the most important crops of the world and provides food, feed, and several by-products. It is a staple food crop for many of the countries in the world (Curna and Lacko-Bartosova, 2017). Wheat is an important source of carbohydrates. When eaten as a whole grain, wheat is a source of multiple nutrients and dietary fiber (Shewry and Hey, 2015). Wheat is grown on more than 215,901,958 hectares of the world, a larger area than any other crop with the production of 765 million tons (FAO, 2019). In Bangladesh among the cereals, wheat is second to rice in economic and consumption importance (Rashid and Hossain, 2016). In 2018-19, the total production of wheat in Bangladesh was 10, 16,811 metric tons in an area of 3,30,348 hectares (BBS, 2019).

Bangladesh agriculture in the 21st century is facing versatile challenges during crop production (SRDI, 2010). Several social, edaphic, biological, and climatic constraints hinder wheat productivity. Even though most of the wheat varieties developed by the researcher in Bangladesh are high-yielding varieties, production of those wheat varieties did not keep pace sufficiently matching with the increasing demand for wheat (WRC, 2018). Weeds are among the most important biological constraint, limiting wheat productivity if they are not controlled properly.

Weeds are undesirable plants, which infest different crops and inflict a negative effect on crop yield either competition for water, nutrients, space, and/or light (Masum *et al.*, 2016). Weeds are notorious yield reducers that are, in many situations, economically more important than insects, fungi, or other pest organisms. Weed flora in wheat has shown marked changes over the years because of the repeated use of the same herbicide, resource availability, and changes in cropping systems and tillage practices. The likely grain yield decrease in wheat caused by weeds maybe around 18.6% (Gharde *et al.*, 2018) due to a reduction in tillering of wheat (Chhokar and Malik, 2002). Weeds constantly compete with crop plants to cause a considerable loss in their productivity. The intensity of weed-caused losses depends upon weed type, density, emergence time, and interference duration; and simultaneous weed emergence with the crop intensifies competition for limited growth resources, increasing the risk of severe crop yield losses (Hussain *et al*., 2015). Hence, weeds have been documented as serious plant pests since ancient times (Zimdahl, 2013). Hossain *et al*. (2009) reported *Cynodon dactylon, Eleusine indica, Digitaria sanguinalis, Cyperus rotundus, Chenopodium album, Oxalis europea, Physalis heterophylla, Vicia hirsuta, Hedyotis brachypoda* and *Stellaria media* as the most common weed species occurring in the wheat fields in Bangladesh.

Other than causing yield losses, weeds also cause hindrances in the agronomic management of wheat and increase its cost of production. Hence, effective weed control is required to achieve an optimum and sustainable grain production of wheat. Although cultural practices are also used occasionally, the use of herbicides has been a major method of controlling weeds in wheat. Generally, weed control has been characterized by using heavy herbicides, which has resulted in environmental problems as well as the emergence of weeds resistant to herbicides (Duke, 2005). However, during recent times, factors such as herbicide resistance evolution in weeds and environmental pollution caused by herbicides stress the need for weed control methods other than herbicides. Further, there is a demand by organic growers for weed suppressive cultivars. In recent years, there has been considerable desire to reduce herbicide use and search for alternative ways to control weeds (Ackerman *et al.*, 2014). Managing crop fields according to nature's principles can reduce weed problems. Hence, the phenomenon of allelopathy that can be manipulated to suppress weeds without herbicide application becomes important for weed control.

Allelopathy refers to the suppression of growth of one plant by another due to the release of toxic substances mainly secondary metabolites. It explains the inhibitory and stimulatory interactions in the soil plant interface through biochemical pathways. Masum *et al.* (2019a) stated allelopathy as the direct or indirect harmful or beneficial effects of one plant to another plant from the release of biochemicals (allelochemicals) into the environment. Secondary metabolites released by a plant species or organism that influence the germination, physiology, growth, survival, and reproduction of others are known as allelochemicals. Thus, allelopathy is a phytotoxic interference in most circumstances and indirectly provokes other forms of stress. There is a wealth of information on plant-plant allelopathic interactions in natural and managed ecosystems (Belz, 2007; Kong *et al.* 2016; Masum *et al.*, 2019b). Allelopathy, the chemical interference between plants, is receiving increasing interest as different systems of integrated weed management for organic and low-input agricultural systems develop (Olofsdotter *et al*., 2002; Belz, 2007). Practical weed control can be achieved by using allelopathy. Importantly, such weed control will neither harm the environment nor increase weed management costs. Allelopathic crop species can produce and release their herbicides, i.e. allelochemicals to interfere with associated weeds. So, more effort has given into exploiting allelopathic crops as an important part of integrated weed management in recent years (Farooq *et al.*, 2011). Allelopathic weed control may be applied as a single strategy in certain cropping systems, such as organic farming. Further, it can be combined with other methods to achieve integrated weed management. Under allelopathic weed control, the allelopathic potential of crops is manipulated in such a way that the allelochemicals from these crops reduce weed competition. In the coming years, utilizing the allelopathic potential of a crop could be a promising tool to manage weeds effectively by the weed-suppressing ability of crop varieties themselves (Khaliq *et al*., 2014). Fortunately, a few crop varieties with weed-suppressive effects have been identified from several germplasm collections including wheat (Kong *et al*., 2011; Wu *et al*., 2000a). Benzoxazinoids and phenolic compounds are the most important allelochemicals reported in wheat (Jabran, 2017).

Weed management in current agriculture relies on herbicides because they are highly effective (Gianessi, 2013). But they are harmful to the environment as well. The use of allelopathy (an eco-friendly measure) as an important ecological phenomenon to control weeds in different crops is now practicing worldwide (Biswas *et al*., 2008). So to reduce the use of chemical herbicide, careful selection of suitable wheat varieties is necessary for a continuous cropping system to minimize the negative impacts of varietal allelopathy and weed infestation as the allelopathic potential of wheat varieties is correlated with their heredity and allelochemicals released into the environment under natural conditions (Kong *et al.,* 2002). Importantly, the allelopathic activity of wheat can be channelized to achieve an environment-friendly weed control (Wu *et al.* 2003a).

Since there is scarce advanced research on Bangladeshi wheat allelopathy, the research on identifying allelopathic potential Bangladeshi wheat varieties will be very decisive for the development of allelopathy-based sustainable weed management. Therefore, the main objective of the present research was to find out the allelopathic potential wheat varieties of Bangladesh.

The specific objectives of the research:

- Determine the biological activity of Bangladesh wheat varieties on the root and shoot growth of *Chenopodium album*, *Amaranthus viridis*, *Raphanus sativus* and *Lactuca sativa*.
- Screen out the allelopathic potential of Bangladesh wheat varieties.
- Correlate the field performance of wheat in terms of weed control with *in vitro* screening.

CHAPTER 2

REVIEW OF LITERATURE

Very few research works related to the 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 the allelopathic effect in controlling weeds in wheat and some other 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 effects of wheat

Wang *et al.* (2019) found a significant allelopathic interaction between wheat and *Aegilops tauschii*. Both of them were allelopathic on each other seedling growth and it is expressed as a promotion at low concentrations but inhibitory at high concentrations on the growth of seedling height and root length. Adaptation of wheat or *A. tauschii* seedlings to the allelopathic stress from the other depends on a constant increase in proline content and SOD activity. The synthetic allelopathic effect showed that, at 10-100 mg mL^{-1} concentrations, the aqueous extracts of *A. tauschii* stem and leaves had higher allelopathic inhibitory effects on wheat seedlings than the aqueous extracts of roots. At 25-100 mg mL^{-1}, the aqueous extracts of wheat had similar allelopathic inhibitory effects on *A. tauschii* seedlings. That strong allelopathic inhibition on seed germination and seedling growth may be the important reason for its large-scale invasion in the wheat field.

Kong *et al.* (2018) experimentally demonstrated neighboring detection and allelopathic responses between wheat and 100 other plant species amid belowground signaling. Wheat can detect both conspecific and heterospecific neighbors and responds by increasing allelochemical production. Furthermore, they showed that loliolide and jasmonic acid were present in root exudates from a diverse range of species and can trigger allelochemical production in wheat. These findings suggested that root secreted loliolide and jasmonic acid are involved in plant neighboring detection and allelochemical response and may be widespread mediators of belowground plant-plant interactions. When wheat was paired with itself and eight common weeds (*Eleusine indica, Digitaria sanguinalis, Abutilon theophrasti, Bidens frondosa, Lolium perenne, Avena fatua, Alopecurus japonicus and Aegilops tauschii*) that often come into contact with wheat, allelochemical DIMBOA concentration varied with the density of the neighbors.

According to Kong *et al*. (2016), allelopathic wheat inhibited the growth of five weed species and the allelochemical production of wheat was elicited in the presence of those weeds. The inhibition and allelochemical levels varied greatly with the mixed species density. Increased inhibition and allelochemical levels occurred at low and medium densities but declined at high densities. All the root exudates and their components of jasmonic and salicylic acid from all five weeds stimulated allelochemical production. Furthermore, jasmonic acid and salicylic acid were found in plants, root exudates and rhizosphere soils, regardless of weed species, indicating their participation in the signaling interactions defined as allelobiosis. Thus wheat can detect competing weeds and respond by increased allelochemical levels to inhibit them, providing an advantage for its growth.

Kashif *et al.* (2015) studied the allelopathic interaction of wheat and littleseed canarygrass using the equal-compartment-agar method. Wheat cultivars and promising lines (Faisalabad-08, Lasani-08, Shafaq-06, Sehar-06, Miraj-08, Farid-06, Chakwal-50, V-04178, V-05066 and V-05082) were used to study their allelopathic interaction with littleseed canarygrass. Each wheat cultivar was grown alone and in association with littleseed canarygrass in glass beakers containing water agar solution. Littleseed canarygrass was also grown alone as the control for comparisons. Results revealed that wheat cultivars had differential allelopathic inhibition activity against littleseed canarygrass through the production of phenolic compounds. Maximum inhibition in root length (54%), shoot length (59%), root dry weight (60%) and shoot dry weight (55%) of littleseed canarygrass was recorded when grown in association with wheat cv. Shafaq-06, while all these growth parameters were less in association with cv. Sehar-06. A significant increase in production of total soluble phenolics was also observed in the root and shoot of all wheat cultivars when grown in association with littleseed canarygrass as compared to when grown alone. In conclusion, cv. Shafaq-06 was found strongly allelopathic against littleseed canarygrass.

As per the report of Yaseen and Hussain (2014) wheat has its allelopathic potential against rice seedlings under field conditions. Allelopathic studies had been designed by using aqueous both cold and hot extracts from root and shoot straw, leachates, and mulching in various pot experiments, invariably reduced the plant height, length of leaf, width of leaf, number of spike per plant, length of the spike, number of seeds per spike and size of internode of the rice plant used as the test species. The aqueous extracts obtained after 48 h were more inhibitory than 24 h. similarly, 10 % W/V extracts were more inhibitory than 5 % W/V extracts. Leachates and mulching experiments also proved to be inhibitory. It was found that both wheat root and stem straw have strong allelopathic potential against the rice plant.

Mardani *et al.* (2014) reported the allelopathy potential of 9 wheat cultivars against rye (*Secale cereale* L.). Images were captured every 12 h to evaluate the effects of wheat cultivars on rye seedling growth over time. The rye seedling growth was significantly affected by the allelopathy of different wheat cultivars. The root surface area and spread (root architecture) of rye were decreased by more allelopathic cultivars in the growing medium. There was a clear correlation between the root spread of rye and seedling growth, suggesting the potential of root spread as an important parameter of allelopathic activity. This method provided a consistent and reliable tool for analyzing the changes in root architecture of allelochemical receiver plants during exposure to allelopathic neighbors.

Lu *et al.* (2012) explored the effect of proximity of two weeds (wild oat and flixweed) on DIMBOA/MBOA production in wheat seedlings under hydroponic culture to identify if the breeding of modern wheat varieties with higher concentrations of these compounds could ensure plant-mediated weed control. MBOA was detected and was noted to exert a significant response; its exudation by some wheat seedlings was significantly increased irrespective of whether the roots were in contact with or separate from those of the weeds. The weeds were a source of biotic stress to wheat when grown in proximity to it, and the stress resulted in the production of higher levels of MBOA in wheat seedlings, although the concentration varied with the wheat cultivar. Therefore, the synthesis and exudation of DIMBOA/MBOA in wheat seedlings appears to be an active metabolic process influenced by the environment, particularly the presence of weeds.

Khaliq *et al*. (2012) investigated the toxic action of aqueous wheat (*Triticum aestivum*) straw extracts on germination, early seedling growth, some biochemical attributes and the antioxidant enzymes of horse purslane (*Trianthema portulacastrum*). Aqueous extracts of wheat straw were prepared by soaking the wheat straw in distilled water in a 1:10 w/v ratio and diluted to obtain the concentrations of 0, 25, 50, 75, and 100%. These were used as pre and post-emergence in laboratory and screen house trials. Wheat aqueous extracts exhibited phytotoxicity to horse purslane by inhibiting and delaying its germination and suppressing seedling growth. Wheat phytotoxins in its aqueous extracts suppressed the chlorophyll content and soluble protein, and enhanced soluble phenolics and the activity of antioxidant enzymes as catalase, peroxidase, and superoxide dismutase in the seedlings of horse purslane compared with the control. Such inhibitory activity is believed to originate from exposure to wheat phytotoxins that are present in its aqueous straw extract.

Bertholdsson *et al*. (2012) researched allelopathic sources among accessions of *Triticum, Secale*, *Triticosecale,* and wheat-rye substitution and translocation lines to be used in breeding programs to improve weed suppression ability of wheat. A bioassay with mustard as target plants was used for the screening. Mustard was chosen among seven tested target plants as it showed a particular high root growth inhibition when grown together with rye compared with wheat. Several of the wheat-rye substitution and translocation lines showed high allelopathic activity. The highest activity was found in lines with a substitution of 1R or 2R. Some multiple substitution lines and lines with only rye chromatin also showed high allelopathic activity. It is suggested that *in vitro* selection of wheat-rye substitution lines with high allelopathic potential with a bioassay with mustard as target plants could be used to improve the weed suppression ability of wheat.

Li *et al*. (2011) conducted a laboratory bioassay for the assessment of the effects of wheat (*Triticum aestivum*) crop density on weed control of annual ryegrass (*Lolium rigidum*). Increasing the density of allelopathic wheat strongly ameliorated its competitiveness and significantly inhibited the growth of annual ryegrass. The increased wheat density steadily decreased the total root length and root surface area of ryegrass, however, the root diameter of ryegrass increased. The roots of annual ryegrass were thinner than wheat. Interactions between the wheat and annual ryegrass greatly influenced the annual ryegrass root length and diameter within 0.180-0.225 mm and within 0.225-0.270 mm. In addition, root distribution and dominance in different diameter classes were wheat density-dependent and uneven. The increased root diameter and decreased root length and surface area of ryegrass may be due to strong allelopathic effects of wheat (a significant quantity of allelochemicals were produced at middle and high densities). This might lead to the suppression of annual ryegrass growth.

Khaliq *et al*. (2011) evaluated the suppressive activity of decomposing wheat (*Triticum aestivum*) straw and rhizosphere-infested soil against horse purslane (*Trianthema portulacastrum*), a noxious summer weed in Pakistan. Two separate pot studies were carried out. Wheat straw was incorporated at 4, 6, and 8 g kg^{-1} soil five days before the sowing of horse purslane. Pots without straw incorporation were maintained as control. In a second study, the soil was taken from 15 and 30 cm depths from a previously cropped wheat field immediately after its harvest and was used as a growing medium. Soil from an intentionally uncropped area of the same field was used as control. The suppressive activity was measured in terms of germination dynamics, seedling growth, and biochemical attributes such as chlorophyll contents, total soluble phenolics, soluble protein, and antioxidant enzymes. Germination, seedling growth, chlorophyll contents and soluble protein of horse purslane were all negatively influenced. Higher phenolics and enhanced activities of antioxidant enzymes were noticed in response to wheat residues incorporation and its rhizosphere soil. Both studies established that the phytotoxic influence of wheat straw and wheat-infested rhizosphere soil on horse purslane can further be exploited for horse purslane management as a sustainable approach.

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

Bertholdsson (2010) examined a breeding program in spring wheat (*Triticum aestivum*) to determine the efficiency of selection of allelopathy and the ability of breeding lines to suppress weeds in the field. The material he used originated from a cross between a Swedish cultivar with low allelopathic activity and a Tunisian cultivar with high allelopathic activity. The allelopathic activity was measured as growth inhibition of perennial ryegrass (*Lolium perenne*) roots when grown together with the wheat cultivars on agar media. For screening of F_2 populations, a single plant bioassay was used. In the F_6 and F_7 generations, three breeding lines with average improved allelopathy of 20% and one line with an unimproved allelopathy activity, but with the same phenotype as the high allelopathic lines, were tested together with the low allelopathic Swedish parent. The main result from the field study was a 19% average reduction of weed biomass for the high allelopathic lines, but no significant reduction of the low allelopathic breeding line. Early shoot length and early crop biomass and straw length of the high allelopathic lines were not significantly different from the Swedish parent. A negative effect was that grain yield was reduced by 9% in the high allelopathic lines. It is suggested that the reduced biomass of weeds in plots planted with the highly allelopathic wheat lines is related to differences in allelopathic activity and not differences in plant growth.

The equal compartment agar method (ECAM) was employed by Labbafi *et al*. (2010) to evaluate four allelopathic activity wheat cultivars on whole plant, root and shoot length, and plant dry weight of four weed species. Wheat cultivars were included Niknejad, Shiraz (more competitive cultivars), Tabasi and Roshan (less competitive cultivars). In this study, author used four weed species (*Secale cereale, Avena ludoviciana*: monocotyledon, *Convolvulus arvensis* and *Vicia villosa*: dicotyledon). Results showed that the allelopathic activity of wheat was associated with the number of wheat seedlings and wheat cultivars. Results demonstrated that the whole plant and root length of weed species were significantly reduced in the presence of wheat cultivars. The degree of weed growth inhibition was depended on the number of wheat seedlings. All of the cultivars and densities caused the promotion of dicot shoot length. Results indicated that the length of the whole plant (-30.22%) and root (57.74%) of *C. arvensis* and shoot length (-13.24%) of *S. cereale* had the highest sensitivity. None of the factors had a significant effect on the plant dry weight of weed species.

Flood and Entz (2009) evaluated the compared allelopathic effects of three winter cereals, winter wheat (*Triticum aestivum*), winter rye (*Secale cereale*), and winter triticale (*Triticale hexaploid* Lart.) on seed germination of redroot pigweed (*Amaranthus retroflexus*), green foxtail (*Setaria viridis*) and common bean (*Phaseolus vulgaris*). Extracts from the field and greenhouse-grown rye significantly inhibited germination of redroot pigweed and green foxtail, yet did not affect the navy bean cultivar Envoy. In a second study, rye, wheat, and triticale provided similar inhibition of weed seed germination; however, effects on bean germination differed between cereals. Bean seed germination was significantly reduced ($P<0.05$) by winter wheat and winter triticale, but unaffected by rye.

Drews *et al.* (2009) trailed winter wheat (*Triticum aestivum*) at different sites in North Rhine-Westphalia, Germany. The aim was to evaluate the performance of three varieties, which differ in their shading behavior, in suppressing weeds under organic farming conditions and grown at three-row spacing. The experimental factors were cultivar, row width, and row orientation. Key parameters of crop and weed development, including ground cover and biomass, were assessed at different growth stages and analyzed with ANOVA. Growth of the site-specific weed vegetation was significantly affected in five of six trials. Weed growth was reduced by cvs Astron and Pegassos compared with cv. Greif, and was lower at 12 cm compared with 24 cm row spacing. No effect of row orientation (East-West, North-South) on weed growth was observed. The more competitive cultivars Astron and Pegassos were taller than the less competitive cv. Greif and had higher ground cover and light interception, presumably induced by planophile leaf inclination and partly, in the case of cv. Astron, because of higher leaf area index (LAI). Narrow row spacing, resulting in more even spatial plant distribution, increased crop ground cover, LAI, dry matter and light interception. In two trials, the variety with planophile leaf inclination performed better at wider row spacing, suggesting that planophile wheat cultivars may be advantageous in wider row stands.

Bensch *et al.* (2009) evaluated the allelopathic potential of 50 wheat cultivars on four weed species associated with this culture in south Chile. The longest main root of the receptive species (weed) was evaluated eighteen days after the establishment of the last one. The transformed data into the percentage of inhibition of root length of the receptive species concerning the control was analyzed using ANDEVA, cluster analysis, and Tukey ($P \leq 0.05$). The allelopathic potential of fifty wheat cultivars in most cases root development was inhibited and occasionally some weeds were potentiated. The more inhibitory cultivars were Perquenco, Metrenco, Aztec, and Baroudeur (range 57 and 65%) and with less potential Dollinco, Tilburi, Tukan, and Bingo (range 20 and 29%); the other cultivars showed an intermediate inhibition. The interaction allelopathic between wheat cultivars and weed species was: Spergula arvensis (+10 and 88%), Rumex acetocella (+8 and 70%), Avena fatua (+36 and 74%), and Vulpia bromoides (+11 and 68%).

Zuo *et al.* (2008) integrated allelopathic bioassay and point sampling methods to investigate the allelopathic rank of the stubble of different wheat genotypes and its effect on weed biodiversity in a maize field. The study consisted of 17 wheat stubble treatments derived from ten wheat genotypes planted individually (monoculture) or in pairs (mixed culture). The maize was planted in the plots immediately following the wheat harvest and the number of weed species, total weed number, weed density, weed height, and weed cover were determined 50 days later. The results indicate a significant rank effect of allelopathic potential in the stubble of the different wheat genotypes. There was a stronger allelopathic effect from the straw in the mixed-culture treatments compared to the monoculture treatments. The regression analysis showed that the weed biodiversity indices were significantly related to the allelopathic rank. The allelopathic potential exhibited spatial heterogeneity in all the scales, which would trigger resource heterogeneity and change the microhabitat conditions. Therefore, weed biodiversity would respond spatially and biologically to the heterogeneous distribution of allelochemicals from the wheat stubble. The allelopathic rank of the wheat stubble would lead to changes in weed biodiversity by regulating the ecological niche of the weed population. This study on the effect of allelopathic potential on weed biodiversity provides a solid theoretical basis for sustainable weed management of agro-ecosystems.

Wheat varietal autotoxicity and varietal allelopathy were assessed by Wu *et al.* (2007) based on plant extract and root exudate bioassays under laboratory conditions. They found that aqueous extract of wheat differed in varietal autotoxicity and varietal allelopathy, inhibiting wheat germination by 2-21%, radicle growth by 15-30%, and coleoptile growth by 5-20%, depending on the combination of the receiver and donor. They worked with four where extracts of cv Triller or cv Currawong were more allelopathic to other wheat varieties than cv Batavia and cv Federation. Triller extract was more autotoxic than Federation. Assessment of root exudates by the equal-compartment-agar-method further identified the significant differences in varietal autotoxicity and varietal allelopathy of root exudates between wheat varieties, with root exudates of Triller or Batavia showing stronger autotoxic or allelopathic effects than Currawong or

Federation. The varietal autotoxicity and allelopathy of root exudates also showed a characteristic radial inhibitory pattern in the agar growth medium.

Zuo *et al.* (2007) investigated the genetic variation of allelopathic potential, its grey correlation with important agronomic characters, and rank analysis on allelopathic stability of fifteen wheat accessions commonly grown in arid regions of the Loess Plateau in China. The genetic variation of allelopathic property in dryland winter wheat showed significant differences between accessions. Allelopathic effects exhibited high heritability (55–95%) throughout the life cycle of wheat. Heritability was highest in the tillering stage and weakest in the seed filling stage. Allelopathic potential varied and was discontinuous throughout the wheat life cycle. Grey correlation analysis indicated a close relationship between allelopathic potential dependant on the growth phase and agronomic characters. Allelopathic expression during some growth periods induced a partial correlation effect on some important agronomic characters that affected wheat yield. Allelopathic heritability and its degree of influence on yield were more evident in the vegetative growth stage compared to the reproductive stage. Multiple linear regression was built between allelopathic potential during different growth periods and agronomic characters pursued in wheat breeding. Allelopathic potential had a linear effect on production traits cultivated in wheat breeding. When allelopathic intensity varied from 0 to 1 in the reproductive stage, plant height ranged from 44 to 108 cm, spike length from 6.4 to 9.2 cm, number of spikelets with seeds from 13.4 to 21.0, mean seed number per spike from 41.5 to 50.3 and thousand seed weight from 36.2 to 38.3 g. Based on the rank analysis, we concluded that there was a synergistic relationship between the allelopathic potential in wheat and genetic, chemical and ecological factors. *Triticum aestivum* L. 'No 6 Lankao' and *T. aestivum* L. 'No 22 Xiaoyan' were identified as stable and relatively strong allelopathic accessions, whereas *T. aestivum* L. 'Lankao 95–25' was a stable but relatively weak allelopathic cultivar. Other varieties showed unstable allelopathic potential.

Nakano *et al.* (2006) reported that when seedlings of lettuce, cress, rice and wheat were incubated with the leachate of wheat straw, the roots growth of lettuce and garden cress were particularly inhibited. The leachate of wheat straw (100 g eq./l) showed 80.5 and 79.4% inhibition for lettuce and cress roots, respectively. The inhibitory activity was stronger as the concentration of wheat straw leachate was greater. This result indicates that allelochemical(s) inhibiting the growth of the roots of lettuce and cress are leached from the wheat straw into the water. Two potent compounds were isolated from the leachate of the wheat straw and identified as syringoylglycerol 9-*O*-β-d-glucopyranoside and l-tryptophan by spectral analyses. Syringoylglycerol 9-*O*-β-d-glucopyranoside inhibited the growth of the roots of lettuce and cress at concentrations greater than 0.1 and 10.0 μM, respectively. On the other hand, l-tryptophan inhibited the growth of the roots of lettuce and cress at concentrations greater than 0.1 and 1.0 μM, respectively. The content of syringoylglycerol 9-*O*-β-d-glucopyranoside and l-tryptophan in the leachate of wheat straw (100 g eq./l) was 18.4±0.7 and 6.2±0.6 μM, respectively. Syringoylglycerol 9-*O*-β-d-glucopyranoside (18.4 μM) showed 21.5 and 13.5% inhibition in the lettuce and cress roots assay, respectively. On the other hand, 6.2 μM of l-tryptophan showed 47.5 and 35.0% inhibition in the lettuce and cress roots assay, respectively. These results suggested that l-tryptophan may be a major contributor to the allelopathy in aqueous leachate of wheat straw and syringoylglycerol 9-*O*-β-d-glucopyranoside may be a minor contributor.

Krogh *et al.* (2006) incorporated wheat and rye sprouts into the soil to follow the fate of the allelochemicals. In the wheat experiment, MBOA was detected as a main allelopathic compound. HMBOA and HBOA were detected as well. That study showed the dynamic pattern of biologically active benzoxazinone derivates in the soil after the incorporation of wheat and rye sprouts**.**

Mathiassen *et al.* (2006) examined the possibility of exploiting the allelopathic properties of wheat as a weed control strategy by cultivating wheat as a pre crop and incorporating plant residues into the soil before the next crop is sown. Different wheat varieties were cultivated infield plots during two seasons in both conventional and organic farming systems. Plants were sampled at various growth stages, and their contents of DIMBOA, MBOA, and BOA were determined by chemical analyses. The wheat samples were incorporated into the soil, and the effect on germination and growth of 12 different weed species was examined in pot experiments under controlled conditions. In some cases, significant effects were obtained, but the results were inconsistent and the effects were not correlated to the content of DIMBOA, MBOA, and BOA in the incorporated wheat plants. ED50 doses of the pure compounds were estimated in dose-response experiments in Petri dishes, and these turned out to be much higher than the predicted maximum concentrations of DIMBOA, MBOA, and BOA in the soil water following incorporation. The study shows that a prerequisite forexploiting the incorporation of wheat residues as a weed control strategy is the development of wheat varieties with increased content of allelochemicals.

Zuo *et al.* (2005) studied allelopathic effects of 10 wheat genotypes in bioassays on germination and root length of lettuce. The germinating wheat seeds and seedlings of all genotypes inhibited the radicle elongation of lettuce. Excluding Secale cereale L., the inhibitory effects of wheat genotypes increased with wheat evolution history, as the genome changed from 2n to 4n to 6n. Allelopathic inhibition of different wheat genomes on lettuce radicles showed a decreasing trend of AABBDD > BB > AABB > RR > AA > DD. This suggests that the allelopathic genes may be located on genome BB and the allelopathic traits in the genomes may have evolved at different rates. The allelopathic effects of 10 spp. were correlated with the age (20, 40, 60 d) of the seedlings. The allelopathic effects of different plant parts decreased in order aerial parts > whole plant > roots. A cluster analysis (Unweighted Pair Group Method using Arithmetic averages, UPGMA) was conducted for the allelopathic effect of 10 spp. at germination and seedling phases. In cluster analysis wheat spp. were divided into three categories based on their allelopathic effects on lettuce radicle, (a) Weak allelopathy, (b). Moderate allelopathy and (c) Strong allelopathy.

Liang *et al*. (2005) worked with 27 local wheat (*Triticum aestivum*) varieties with different origins and agronomic traits from a Chinese wheat germplasm collection to evaluate their allelopathic potential against lambsquarters (*Chenopodium album*) and redroot amaranth (*Amaranthus retroflexus*). Six varieties were found to demonstrate obvious allelopathic potential using pot culture and equal-compartment-agar methods. Root growth of test weeds *C. album* and *A. retroflexus* were significantly inhibited by these allelopathic wheat varieties. Results suggested that the allelopathic potential of wheat germplasm might be evaluated by a combination of multiple methods.

Bertholdsson (2005) revealed that in both barley and wheat, early crop biomass and potential allelopathic activity were the only parameters that significantly contributed to competitiveness. In barley, early crop biomass explained 24-57% of the observed genotypic variance across 4 years, allelopathic activity explained 7-58% and combined they explained 44-69% of the observed genotypic variance. In wheat, the corresponding figures were lower, 14-21% for early biomass, 0-21% for allelopathic activity, and 27-37% when combined. Model predictions suggested that new cultivars with increased early vigor and allelopathic activity offer the potential to further reduce weed interference.

Bruce *et al.* (2005) conducted field experiments in southern New South Wales to determine the effect of surface-retained wheat stubble on the emergence, growth, and yield of canola. The five experiments included treatments to investigate the impact of stubble load, stubble cultivar, and level of decomposition as well as the impact of different environments on the crop response. Overall, 5 t ha^{-1} of surface retained wheat stubble reduced the rate of emergence, plant establishment (mean reduction 33%), vegetative biomass (–56%), and yield (–23%), although the impact varied with site and season. Laboratory experiments assessing the phytotoxicity of stubble revealed the possible role of allelopathy in the growth response at 1 site; however, there was no correlation between laboratory phytotoxicity of different stubble cultivars and their impact on canola growth at any other site. Wheat stubble comprising thinner stems (lower straw linear density) had a greater impact on emergence at 2 of the sites, indicating a possible role of reduced light penetration in the growth response. Colder temperatures on the surface of the stubble also reduced emergence and growth and caused seedling death at the coldest sites. The experiments confirm the widely observed phenomenon of poor canola growth in surface-retained wheat stubble, and suggest several possible mechanisms for the effect, although further studies are required to determine their relative importance in different environments.

Wicks *et al.* (2004) indicated thirteen hard red winter wheat cultivars allelopathic for their ability to suppress summer annual weeds in grain production systems near North Platte, NE, from 1993 through 1997. Turkey, a 125 years old landrace selection, suppressed both broadleaf and grass weeds more than other cultivars. Some relatively new cultivars, such as Arapahoe, Jules, Pronghorn, and Vista suppressed summer annual grasses almost as well as Turkey. Total weed density was negatively correlated with the number of winter wheat stems m^2, mature winter wheat height, and lodging. Weed density after wheat harvest was positively correlated with a delay in winter wheat seeding date and was negatively correlated with precipitation 0 to 30 d after winter wheat seeding, during tillering, tillering to boot stage, and heading to maturity stage. Mean air temperature 0 to 30 d after wheat seeding was positively correlated with weed density. In the spring, weed density was positively correlated with temperatures during the tillering stage, tillering to boot stage, and heading to maturity stage. Stinkgrass and witchgrass densities were positively correlated with the severity of wheat leaf rust. The highest grain-producing cultivars included three medium height cultivars Alliance, Arapahoe, and Niobrara. Alliance wheat produced 53% more grain than Turkey, and the other two produced 43% more grain.

Wu *et al.* (2003a) accessioned 39 wheat to evaluate their extract phytotoxicity against annual ryegrass (*Lolium rigidum*). Aqueous extracts of wheat shoot residues significantly inhibited the germination and root growth of two biotypes of annual ryegrass, herbicides resistant (HR) and herbicides susceptible (HS). Phytotoxicity of wheat aqueous extracts (1/3 of the full strength) differed significantly among cultivars. Of the 39 wheat cultivars tested, 16 accessions significantly reduced HR ryegrass root growth by more than 80%, and five accessions by less than 50%. Two accessions, Angus and Jing Hong stimulated the root growth, with a length of 47.7 and 49.0 mm, respectively, compared to a water control of 43.7 mm. Seed germination of HR ryegrass was inhibited by 3-100% depending upon the accession. The phytotoxicity of wheat extracts was more pronounced against root growth than seed germination of ryegrass. To determine the differential responses of HR and HS biotypes of annual ryegrass to wheat extracts, the HS biotype was included as a reference. Results showed that 10 wheat accessions significantly reduced HS ryegrass root elongation by more than 80%, while 24 accessions gave less than 50% root length reduction in ryegrass. The aqueous extracts of Sunbri and Kallalac not only significantly inhibited seed germination but also coincided with the strong inhibition over the root elongation of HS ryegrass, with a length of 2 and 1 mm, respectively, in comparison with a water control of 77 mm.

Oueslati (2003) evaluated the allelopathic effects of diluted extracts from the roots, leaves and stems of two varieties of durum wheat (*Triticum durum*) on germination rate and radicle length of one barley (*Hordeum vulgare*) and one bread wheat (*T. aestivum*). The leaf extract was more effective at depressing radicle length in both crops. Based on the results, the author suggests that durum wheat heterotoxicity could be depressive to crops in a sequence.

Om *et al.* (2002) experimentally demonstrated the allelopathic response *Phalaris minor* in rice-wheat system. Out of them, wheat variety WH533 had a 29.96% inhibitory effect on the emergence of *P. minor* followed by WH542 (20.89%). The rest of the wheat varieties viz., WH283, WH711, PBW343, HD2687, UP2338, HD2329 could not exhibit more than 20 percent inhibitory effect. Three varieties WH912, HD2687, and WH711 had the lowest inhibition (<10%) of germination.

Korres and Williams (2002) worked with the differential competitive ability of six winter wheat cultivars and traits that confer such attributes were investigated for a range of seed rates in the presence or absence of weeds for a naturally occurring weed flora in two successive years in split-plot field experiments. Crop height and tillering capacity were considered suitable attributes for weed suppression, although competitiveness is a relative rather than an absolute characteristic. Maris Huntsman and Maris Widgeon were the most competitive cultivars whereas Fresco was the least competitive. Manipulation of seed rate was a more reliable factor than cultivar selection for enhancement of weed suppression, although competitiveness of cultivars Buster, Riband and Maris Widgeon was not enhanced by increased seed rate. Crop densities ranging between 125 and 270 plants m^2 were found to offer adequate weed suppression. Linear relationships were observed between individual and total weed species dry weight and reproductive structures per unit area.

Al Hamdi *et al.* (2001) discussed the phytotoxicity of wheat (*Triticum aestivum* L.) straw leachate to the seedling growth of perennial ryegrass (*Lolium perenne* L.). Allelopathy involves complex plant to plant chemical interactions. The results showed the phytotoxic nature of wheat straw leachate (WSL) and the possible involvement of organic molecules in the growth inhibition of perennial ryegrass.

Inderjit *et al.* (2001) observed the interaction between wheat and perennial ryegrass seed density and seedlings of different Ages. Under controlled conditions, the root length of perennial ryegrass after sowing was suppressed by wheat, the extent of which was dependent on the density of wheat seeds. The shoot growth of perennial ryegrass, however, was unaffected by the presence of wheat. Perennial ryegrass density had no effect during the first two weeks on wheat seedling growth. The age of wheat seedlings had no appreciable influence on either the root or shoot growth of perennial ryegrass.

Lemerle *et al.* (2001) reported the relative competitive advantage of 12 commercially available wheat varieties against *Lolium rigidum* at several sites in south-eastern Australia. Nearly all the variation in crop grain yield was attributable to the variety × environment effects (81%), with only 4% due to variety × weed × environment effects. Some varieties exhibited an environment-specific competitive advantage, for example, Katunga, Dollarbird, and Hartog, whereas others like Shrike, Rosella, and Janz were relatively poorly competitive in some situations. The introduction of greater genetic variability into wheat is required to significantly increase competitiveness. Alternatively, manipulating crop agronomy, such as increasing crop seeding rate, maybe a practical alternative. The grain yield of weed free wheat was highly positively correlated with the grain yield of the weedy plots, suggesting that local adaptation is important for strong competitiveness, and that wheat breeders in southern Australia may be inadvertently selecting for competitive advantage with weeds when selecting for other traits such as early vigour. The varieties which showed a competitive yield advantage also suppressed *L. rigidum*. A combination of short-term agronomic manipulations and a longer-term breeding effort is needed for increasing wheat competitiveness, and the increasing importance of herbicide-resistant weeds may facilitate this process.

Allelochemicals in the shoot tissues of wheat were identified by Wu *et al*. (2001). The concentration of total identified phenolic acids varied from 93.2-453.8 mg kg^{-1} in the shoots of 58 accessions. The content of each phenolic acid or group was highly associated with other allelochemicals in the shoots of wheat seedlings. Wheat accessions with high levels of total identified phenolic acids in the shoots were generally strongly allelopathic to the growth of annual ryegrass.

The distribution of allelochemicals was systematically studied within the shoots and roots of wheat seedlings by Wu *et al.* (2000a). The exudation of these compounds from the living intact roots of wheat seedlings into the agar growth medium was demonstrated. Wheat accessions inhibited the root growth of annual ryegrass in comparison to a nil-wheat control. There were also differences among wheat accessions in their allelopathic activity against the growth of annual ryegrass. Accessions Tasman and AUS#18060 were strongly allelopathic to ryegrass, yielding a root length of ryegrass of 5.0 and 7.7 cm, respectively. Accessions L 1512-2721 and HY-65 were less allelopathic, with ryegrass root lengths of 34.3 and 38.0 mm, respectively. However, although the root growth of ryegrass seedlings was suppressed by wheat seedlings, the shoot growth of ryegrass was not affected by any of the wheat accessions during the 10-day co-growth period.

Wu *et al*. (2000b) developed a new screening bioassay method, the ‘Equal Compartment Agar Method’ (ECAM), and evaluated 92 wheat cultivars for their allelopathic activity on the inhibition of root growth of annual ryegrass. There were significant differences between wheat cultivars in their allelopathic potential at the seedling stage about the inhibition of root elongation of annual ryegrass, varying from 23.98-90.91% of normal elongation. Rescreening of 22 selected wheat accessions showed that the allelopathic potential of wheat cultivars was consistent between different years under the same experimental conditions.

In another study, Wu *et al*. (2000c) reported that wheat allelopathic activity was normally distributed within the cultivar collection, indicating the involvement of multiple and major genes in conferring the allelopathic trait and suggesting the possibility of breeding for cultivars with enhanced allelopathic activity for weed suppression. In addition, researchers used 453 wheat accessions originating from 50 countries and found that significant differences in allelopathic potential were displayed in this global collection, indicating the involvement of multiple genes in conferring the allelopathic trait. It was found that the living roots of wheat seedlings could exude most of the allelochemicals identified in the shoots and roots into the agar growth medium. The presence of allelochemicals in the agar growth medium demonstrated that wheat seedlings can synthesize and exude phytotoxic compounds through their root system that could inhibit the root growth of annual ryegrass.

Li *et al*. (2000) found that wheat-water extract exhibited an inhibitory effect on *Digitaria ciliaris* seed germination and seedling growth, with the effect varying with the different wheat varieties. In addition, water extracted from different parts of the wheat caused different degrees of inhibition on *Digitaria. ciliaris*.

Hashem and Adkins (1998) studied the allelopathic effect of seven accessions of *Triticum speltoides* (a wild relative of wheat) on *Avena fatua* (wild oats), nine accessions on *Sisymbrium orientale* (Indian hedge mustard), and ten accessions on both species was evaluated using an agar diffusion method. Pre-germinated seedlings of surface-sterilized caryopses of *T. speltoides* were transplanted onto an agar (5 g liter^{-1}) surface contained within a tube of cellulose dialysis membrane. The tube of cellulose dialysis membrane was held vertically within a 1.5 liter plastic box partially filled with 1 liter of agar (5 g liter^{-1}). Surface sterilized caryopses of *A. fatua* or seeds of *S. orientale* were sown onto the agar surface of the box at various distances from the *T. speltoides* seedling. Following two or six weeks (for *A. fatua* and *S. orientale*, respectively) the weed seedlings were removed from the agar and their radicle lengths recorded. Among the 17 *T.*

speltoides accessions tested against *A. fatua*, accession 9 was the only one that significantly reduced radicle length (50%) across the width of the plastic box. Among the 19 accessions of *T. speltoides* tested against *S. orientale*, accession 8 (50%) and accession 10 (18%) were the only ones that significantly reduced length across the width of the plastic box. None of the accessions tested could suppress the radical growth of both weed species.

Opoku *et al*. (1997) reported the effects of wheat straw mulch on the soil concentration of phenolic compounds, which are potentially phytotoxic to corn seedling growth, were examined in plastic pots under controlled conditions in growth cabinets. The corn seedling biomass and radical length were reduced significantly when wheat straw was present only in the top layer of soil. The presence of corn reduced the number of phenolic compounds at days 14 and 42, compared with when corn was absent.

Narwal *et al.* (1997) conducted a field experiment with three wheat straw management practices (removed, burnt, incorporated) and five forage crops (sorghum, pearlmillet, maize, clusterbean, cowpea) and bioassay studies with wheat straw extracts and wheat field soil extracts were conducted. The straw management practices significantly affected the plant stand, plant height, leaf area index, dry matter and yield of fodder crops. Soil incorporation of wheat straw and its burning proved harmful to the crops as compared to its removal. Straw removal benefitted the seed germination and seedling growth and thus increased the crop yields. Aqueous extracts of wheat straw adversely affected the germination and seedlings' growth of test. crops. While bioassay with wheat field soil showed slight inhibitory effects.

Ma *et al*. (1996) found that the allelopathic effects of decomposed wheat straw on the germination of wheat and maize seeds is dependent on the period of decomposition, pH and variety of crop. All acidic extracts inhibited the germination and root growth of test species. All basic extracts mainly inhibited, but in some cases, stimulated seed germination and root growth. The treatments of one-day incubation under pH = 5, 7 and 8 showed significant ($P < 0.01$) inhibition of root elongation of wheat and maize. The treatments of two weeks incubation under pH = 7 showed very strong inhibition of wheat seed germination. Chemical analysis indicated that phenolic acids and organic acids have a strong inhibition effect. Nitrogen (N) containing chemicals had a weaker inhibition effect and in some cases, a stimulation effect.

Li *et al*. (1996) reported that the germination of *Amaranthus retroflexus* treated with the wheat extract (500 mg kg^{-1}) was reduced by 86% and the height and dry weight of *A. retroflexus* treated with the extracts (100 mg m^{-2}) in soil were reduced by 78 and 82%, respectively. Field studies indicated that *Stellaria media* was killed in the soil by application of a wheat extract of 100 mg m^{-2}.

According to Lemerle *et al.* (1996), the competitive abilities of a wide range of genotypes of wheat *(Triticum aestivum*) and durum wheat *(Triticum durum*) against *Lolium rigidum* (annual ryegrass) were examined to determine the potential for breeders to select strongly competitive varieties. The considerable potential within the wheat genotype to breed varieties with greater competitive ability was demonstrated. In 1993, 250 genotypes from around the world were screened and in 1994 subset of 45 (mainly Australian) genotypes were further examined. A uniform density of *L. rigidum* reduced the grain yield of wheat by up to about 80% in 1993 and to 50% in 1994, depending on wheat genotype. Reduction in grain yield was correlated with *L. rigidum* dry matter. Wheat varied in competitive ability with source, and durum whets were less competitive than *T. aestivum.* The old standard wheat varieties (released between 1880 and 1950) suppressed the weed more than all the current varieties, except eight F_1 hybrids. A doubling of the crop seeding rate of 10 of the genotypes in 1994 reduced the biomass of *L. rigidum* by an average of 25% compared with the standard seeding rate. The ranking of competitive ability of varieties at high density was consistent at both seeding rates. The strongly competitive genotypes had high early biomass accumulation, large numbers of tillers, and were tall with extensive leaf display. The potential for breeding enhanced competitive ability in wheat is discussed.

In a wheat-maize double-cropping system, Ma *et al*. (1995) found that weed growth was investigated after wheat variety comparison experiments terminated. Weed suppression effects varied considerably among the varieties. Weed growth in hand-harvested (no stubble left on the surface of the soil) and combine harvested (a 20 cm height wheat stubble left on the soil surface) wheat fields were compared. The results indicated that combine-harvested fields have significantly less weed growth than do hand-harvested fields. Maize pot experiments indicated that straw mulch completely suppressed weed growth.

In greenhouse studies, Zhang and Ma (1994) observed that the effects of wheat straw mulch on maize seedling growth and development depended on the quantity of straw mulched. Maize seedling growth was promoted at low doses of mulch (1.5-4.5 t ha^{-1}) and inhibited at high doses (6.0-7.5 t ha^{-1}). The adverse effects of wheat straw on maize seedling height, shoot fresh and dry weight, root weight and leaf area were related to the release of allelochemicals inhibitory to maize seedling growth. Straw was more toxic in wet years than in normal precipitation years because wet conditions favor the release of toxic compounds from the straw as leachates and enhance microbial decomposition of the biomass, thus leading to the release of toxic compounds. It might be possible to increase the concentration of toxins in the soil solution and plant uptake of them under wet conditions. Wheat straw mulching in normal and dry years increased the maize growth compared to unmulched treatments. Dry and normal conditions might limit the release of allelochemicals.

Rambakudzibga (1991) conducted laboratory experiments to determine the influence of aqueous wheat straw extract on the germination of *Nicandra physalodes, Amaranthus hybridus, Rottboellia cochinchinensis, Portulaca oleracea, Tagetes minuta, Chenopodium album, Acanthospermum hispidum* and *Urochloa panicoides* (common arable weeds in Zimbabwe). Twenty seeds of each of the species were placed in petri dishes, the wheat straw extract was added and the percentage germination of seeds was calculated after 11 d incubation. *A. hybridus* was the only species in which germination was significantly inhibited, falling from 90% in distilled water to 66.25% with wheat straw extract. However, the percentage germination of *N. physalodes, A hispidum, U. panicoides, C. album, T. minuta* and *P. oleracea* was lower in aqueous wheat extract than in distilled water. The reverse was observed for *R. cochinchinensis*.

Alam (1990) quoted that the germination and growth of wheat were decreased significantly by aqueous extract of wheat straw of the same variety.

A study was conducted by Hicks *et al*. (1989) under laboratory, pot and field conditions to investigate the effects of wheat straw on cotton germination, emergence, seedling growth, and lint yield. Laboratory bioassays revealed that cotton seedling development was inhibited by aqueous extracts of wheat straw. Cotton cultivars were screened for the ability to tolerate the inhibitive effects of wheat straw in laboratory bioassays and greenhouse pot studies. Tolerant Paymaster 404 and intolerant Acala A246 were identified and used in experiments. The germination rate and radicle fresh weight of Acala A246 were 75% and 20%, respectively, of the control treatments. The results showed that the inhibitive effects of wheat straw vary among different cotton varieties and that the inhibitive effects could be overcome by limiting wheat residues, increasing the number of cotton seeds sown, and selecting tolerant cotton varieties. The allelopathic effect of wheat stubble indirectly influenced lint yield by affecting population densities.

Lodhi *et al*. (1987) found that the germination rates of cotton and wheat seeds were significantly affected by various extracts of wheat mulch and soils collected from the wheat field. This toxicity was even more pronounced against seedling growth. Five allelochemicals: ferulic, p coumaric, p-OH benzoic, syringic, and vanillic acids were identified from the wheat mulch and its associated soil. Quantitatively, ferulic acid was found at higher concentrations than p-coumaric acid in the soil. Various concentrations of ferulic and p-coumaric acids were toxic to the growth of radish in a bioassay. The functional aspects of allelochemical transfer from decaying residue to the soil and the subsequent microbial degradation within agroecosystems were discussed, particularly as they relate to wheat crop rotation with wheat and cotton in Pakistan.

Wicks *et al.* (1986) stated that there id differences in weed interference among winter wheat (*Triticum aestivum*) cultivars in farmer fields. Identifying more competitive cultivars would be useful in weed control programs. Twenty cultivars of winter wheat were grown with spring germinating weeds during 1979 and 1980 and eight cultivars were grown in 1981 at North Platte, NE on a Typic Argiustoll soil. Cultivars included semi-dwarf through normal statured types and were adapted to a wide geographic area of the Central Great Plains. Lancota selections (NE 78939, NE 78906, NE 78895, NE 78892, and NE 78925) and sister lines NE 78742 and NE 78743 were good weed competitors. Centurk 78, Buckskin, Vona, and Sage were intermediate, while Homestead and several lines with Homestead germplasm were relatively poor annual weed competitors. Several cultivars that were 73 to 78 cm tall were poor competitors with weeds, while most cultivars that were 83 cm or taller were good competitors. NE 78742 (75 cm) and NE 78743 (72 cm) were among the shortest cultivars but were among the best in competitiveness with weeds. Cultivar selection can reduce summer annual weed growth in winter wheat.

Spruell (1984) screened 286 wheat accessions for allelopathic potential in the USA. Root exudates of each accession were compared with those of a commercial strain, T64, for inhibiting root and shoot growth of Japanese brome (*Bromus japonicus*) and fathen (*Chenopodium album*). Five accessions produced root exudates significantly more inhibitory to the root growth than the commercial strain. When accession CI13633 was grown with *B. japonicus* on a one-to-one basis in U-tubes containing aerated Hoagland solution, growth of the weed was approximately 53% of that recorded when grown with T64.

Jessop and Stewart (1983) used wheat straw as mulch to observe the inhibitory effects of that. They found that at a higher temperature (24^{o}C) wheat seed germination and seedling growth were inhibited but under a lower temperature (8^{o}C), wheat and sorghum straw mulching caused a strong inhibition effect.

The allelopathic potential of wheat straw residue was evaluated by Steinsiek *et al*. (1982) on weed-seed germination and seedling growth. The inhibition of weed seed germination and seedling growth was extract, species, and temperature-dependent. The wheat straw extracts prepared by agitating and soaking caused greater inhibition than those obtained by leaching. The descending order of species susceptibility was ivy leaf morning glory (*Ipomoea hederacea*), velvetleaf (*Abutilon theophrasti*), pitted morning glory (*Ipomoea lacunosa*), hemp sesbania (*Sesbania exaltata*), sicklepod (*Cassia obtusifolia*), and Japanese barnyard millet

(*Echinochloa crus-galli* var. frumetaceae). Incubation at 35°C caused the greatest inhibition of germination and growth of weed seed.

Liebl and Worsham (1983) stated that an aqueous extract of field-grown wheat (*Triticum aestivum*) reduced the germination and root length of pitted morning glory (*Ipomoea lacunosa*) and common ragweed (*Ambrosia artemisiifolia*). Phytotoxicity was increased by about 70% when bioassays with the wheat extract on morning glory and ragweed were conducted in the presence of light. Phytotoxic substances were extracted from wheat with 2 N NaOH. The hydrolyzed extract was fractionated by thin-layer chromatography (TLC). The compound isolated by TLC having the greatest inhibitory effects on morning glory germination was identified using mass spectrometry and determined to be ferulic acid (4-hydroxy-3-methoxycinnamic acid). Ferulic acid at 5×10^3 M inhibited the germination and root length of morning glory 23 and 82%, respectively, and prickly sida (*Sida spinosa*) with carpels 85 and 82%, respectively. Crabgrass (*Digitaria sanguinalis*) germination was inhibited 100%. Ferulic acid did not affect ragweed or prickly sida without carpels. Morning glory root and shoot biomass were reduced 52 and 26%, respectively, when morning glory was grown in sand and watered with a 5×10^3 M solution of ferulic acid. Ferulic acid in the presence of prickly sida seed carpels was found to undergo decarboxylation, forming a styrene derivative, 2-methoxy-4-ethenylphenol. The more phytotoxic styrene compound was produced by a bacterium isolated from the carpels of prickly sida seed. The study showed that ferulic acid and other compounds may indeed play a role in reducing the growth of certain weeds in no-tillage cropping systems.

Research reported that fresh wheat straw was more toxic, which inhibited wheat seed germination, seedling growth, and reduced crop yield (Kimber, 1973). The strong inhibitive effect on wheat seed germination could be continued for <18 days. Chemical fertilizers did not ameliorate the inhibitive effect but after 54 days, this effect would disappear.

Kimber (1966) studied the autotoxicity of water extracts from wheat straw. Results indicated that water extracts of wheat straw after six weeks of decomposition inhibited the seedling growth of wheat and oats (*Avena sativa* L.). The maximum inhibition occurred with the extracts of straw decomposed for 2-6 days.

2.2. Weed control efficiency of wheat

Mostafa *et al.* (2020) observed a significant variation for weed control efficiency due to varietal variation which was recorded at 20 and 60 DAS at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh from November 2017 to April 2018 to evaluate the performance of wheat varieties under different weed control methods. At 20 DAS, BARI Gom 29 recorded the highest weed control efficiency (30.72 %) which was statistically similar to BARI Gom 30 (30.72%), and the lowest weed control efficiency (26.06%) was recorded from BARI Gom 28. Hence, a similar result was found that higher and lower efficiency (56.50% and 44.02% in BARI Gom 30 and BARI Gom 28 respectively) whose both were statistically similar to the other one.

Shabi *et al.* (2018) designed research to evaluate the weed competitiveness of ten wheat varieties of Bangladesh by growing them under weedy and weed-free conditions. Plots without wheat (weed monoculture) were also maintained. Results showed that wheat varieties varied widely in their weed competitiveness and yielding ability. Among the wheat varieties studied BARI gom 27 allowed the minimum weed growth (87.0 gm^{-2}) while BARI gom 21 allowed maximum weed growth (188.9 gm-2). Grain yield ranged between 1.9 t ha^{-1} (BARI gom 23) and 3.7 t ha^{-1} (BARI gom 24) under weed-free conditions, and between 1.3 t ha^{-1} (BARI gom 21) and 2.9 t ha^{-1} (BARI gom 28) under weedy conditions. Weed inflicted relative yield loss ranged from 17.8 to 51.2% among the varieties. Although BARI gom 24 was the highest yielder its competitive ability against weed was very poor. On the other hand, BARI gom 28 and BARI gom 30 appeared as the most weed-competitive varieties (17.8 and 24.9% relative yield losses, respectively) with moderate grain yield. BARI gom 30 was the best in terms of yield, but BARI gom 28 ranked first in terms of weed competitiveness. Therefore, considering the high feasibility of growing weed competitive variety as a tool for sustainable weed management, breeding for strongly weed competitive wheat variety with high yield potential is necessary.

Hossain *et al.* (2010) conducted a field experiment at Wheat Research Centre, Dinajpur to identify the weed species growing in association with eight selected varieties and advanced lines of wheat (Sourav, Gourab, Shatabdi, Sufi, Bijoy, Prodip, BAW 1059, and BAW 1064) and to determine their competitive ability against the infesting weeds. The dominant weed species recorded in the experimental field were *Eleusine indica, Echinochloa colona, Cynodon dactylon, Parapholis strigosa, Setaria glauca, Digitaria* spp., *Blumea lacera, Enydra fluctuans, Sonchus oleraceus, Solanum torvum, Nicotiana plumbaginifolia, Physalis heterophylla, Polygonum coccineum, Polygonum hydropiper, Alternanthera philoxeroides, Alternanthera sessils, Fimbistylis miliaceae, Chenopodium album, Oxalis europea, Leucas aspera, Hedyotis brachypoda* and *Stellaria media.*

Siddiqui *et al.* (2010) carried out a field study at the Botanical Garden of the University of Punjab, Pakistan, to investigate the yield losses by 6 commonly occurring and most abundant weeds in the wheat field viz., *Phalaris minor, Rumex dentatus, Coronopus didymus, Medicago denticulate, Chenopodium album* and *Poa annua.* These weeds were grown with two commercially grown wheat varieties viz., Inqalab 91 and Punjab 96 in a 1:1 weed-crop ratio. Punjab 96 proved to be comparatively more efficient against weeds than Inqalab 91.

2.3. Varietal difference in different growth and yield parameters of Bangladeshi wheat

2.3.1. Plant height

Mondal *et al.* (2015) conducted a field experiment at the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during November 2012 to March 2013 to evaluate the response of three wheat varieties viz., BARI Gom 23, BARI Gom 24, and BARI Gom 25 under four levels of nitrogen fertilizer i.e, 75, 100, 125 and 150 kg N ha^{-1}. Results suggested that plant height was significantly affected due to varieties and/or nitrogen levels.

2.3.2. Tiller number

Adam and Jahan (2019) conducted a field experiment to evaluate the growth and yield performance of six high yielding varieties of wheat *viz.*, BARI Gom 23, BARI Gom 24, BARI Gom 25, BARI Gom 26, BARI Gom 27, and BARI Gom 28 in four sowing time. Results indicated that November 15 sown BARI Gom 25 resulted in the highest number of tillers throughout the growth ages.

2.3.3. Number of effective tillers hill $^{-1}$ (no.)

Islam *et al.* (2018) recommended that BARI Gom 25 produce the maximum number of effective tillers (5 hill^{-1}) with three irrigation levels.

An experiment was carried out by Al-Musa *et al.* (2012) at Patuakhali Science and Technology University to study the performance of some BARI wheat varieties under the coastal area of Patuakhali. Four wheat varieties viz. BARI Gom 23, BARI Gom 24, BARI Gom 25, and BARI Gom 26 were planted in the field to evaluate their comparative performance. Among the varieties, BARI Gom 26 produced the highest effective tillers hill^{-1} (18.08).

2.3.4. Leaf area index

Sheibani and Ghadiri (2012) found that competition between weeds and wheat reduced the wheat leaf area index in the weedy check. The integration of split nitrogen application and herbicides significantly increased the wheat leaf area index.

2.3.5. Spike length (cm)

Sultana (2009) observed a significant effect on the spike length of wheat due to weed control treatments. She concluded that a higher duration of crop-weed competition resulted in a shorter spike whereas less duration showed the longest spike. The longest spike (10.29 cm) was with two weedings at 30 and 60 DAS and the shortest spike length (9.45 cm) was a record in no weeding.

2.3.6. Spikelets Spike^{-1} (no.)

Islam *et al.* (2015) demonstrated that wheat variety exhibited significant variations in the number of total spike m^{-2} (215.6 to 243.1), spikelet spike^{-1} (37.56 to 40.37), and 1000 grain weight (36.67 to 40.91g). BARI Gom 21 produced the lighter grain and BARI Gom 24 and BARI Gom 25 produced the heavier grain.

2.3.7. 1000 seeds weight (g)

Hossain *et al.* (2018) demonstrated that wheat seeds sown at a depth of 4 cm resulted in the significantly highest number of seedlings and seminal roots, tallest plants as well as produce heavier seed.

Al-Musa *et al.* (2012) stated that BARI Gom 26 was most effective to produce the higher weight of 1000 grains (49.38 g) and higher grain yield (3.35 t ha^{-1}).

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

Akhter *et al.* (2019) conducted a two-year field experiment with five wheat varieties (BARI Gom 24, BARI Gom 25, BARI Gom 26, BARI Gom 27, and BARI Gom 28) and three seeding rates (100, 120, and 140 kg ha^{-1}). These treatments were performed under irrigation in the WRC research field in Northern Bangladesh to determine the optimum seeding rates for these varieties. Among all varieties, BARI Gom 26 had the highest grain yield while BARI Gom 25 had the lowest grain yield in both years.

Rahman *et al.* (2015) evaluated a field experiment at the Hill Agricultural Research Station, BARI, Khagrachari for two consecutive years (2009-10 and 2010-11) to find out the wheat varietal suitability for hilly environment and investigate the interaction of sowing dates. The experiment was assigned five modern wheat varieties (Shatabdi, Sufi, Sourav, Bijoy, and Prodip). The yield responses of wheat varieties during the two years showed that there were significant varietal differences under the experimental conditions. The variety Bijoy gave maximum grain yield closely followed by Sourav in both years. Shatabdi produced a higher yield under early sowing but the yield was decreased due to late sowing.

Sultana *et al.* (2012) experimented at Agronomy Field Laboratory of Rajshahi University, Bangladesh to evaluate the effect of variety and weeding regime on yield and yield components of wheat. They revealed that BARI Gom 24 produced the highest grain yield (5.33 t ha^{-1}) followed by BARI Gom 22 (4.85 t ha^{-1}), while the lowest grain yield (3.98 t ha^{-1}) was obtained from BARI Gom 21.

Sultana (2009) recorded that the highest grain yield of wheat (3.74 t ha^{-1}) was with two weeding at 30 and 60 DAS. On the other hand, the lowest grain yield (2.57 t ha^{-1}) was observed with no weeding plot.

2.3.9. Yield loss due to weed

Hussain *et al.* (2015) investigated significant variations in wheat growth and yield under the influence of different little seed canary grass densities as well as sowing dates. The study showed that the presence of 40 littleseed canary grass m^{-2} reduced wheat yield by 28% and 34% in mid and late-sown wheat crops, respectively. These losses were much greater than those for infestation of all weeds, excluding little seed canary grass. The economic threshold (ET) levels of little seed canary grass were 6-7 and 2.2-3.3 plants m^{-2} in mid and late-sown wheat crop, respectively. Herbicide should be applied in cases when little seed canary grass density exceeds these levels under respective sowing dates.

Biswas *et al*. (2008) reported that the wheat crop was frequently affected by weeds that cause a reduction of about 20 to 30% of wheat yield. The researchers initiated a two years research project at Sher-e-Bangla Agricultural University, Bangladesh to study the allelopathic effects of *Brassica spp.* to control weeds in wheat.

Based on above research, it is revealed that allelopathic wheat varieties play a significant role in agro-ecosystem. Therefore present research was conducted to evaluate the Bangladesh wheat varieties for assessing allelopathy potential.

CHAPTER 3

MATERIALS AND METHODS

This chapter presents a brief description of the experimental period, site and laboratory description, climatic condition, crop or planting materials, treatments, experimental design and layout, plant or crop growing procedure, fertilizer application, intercultural operations, data collection, and statistical analysis.

3.1. Location

The research was conducted in the central laboratory and agronomic field of the Sher-e-Bangla Agricultural University, Dhaka, Bangladesh (24.09° N latitude and 90.26° E longitudes) during the period from September 2018 to March 2019. The location of the experimental site has been shown in Appendix I.

3.2. Soil

The soil of the experimental area belonged to the Modhupur tract (AEZ No. 28). It was a medium- high land with non-calcareous dark grey soil. The pH value of the soil was 5.6. The physical and chemical properties of the experimental soil have been shown in Appendix II.

3.3. Climate

The experimental area was under the subtropical climate and was characterized by high temperature, high humidity and heavy precipitation with occasional gusty winds during the period from April to September, but scanty rainfall associated with moderately low temperature prevailed during the period from October to March (Khanam *et al.*, 2016). The detailed meteorological data in respect of temperature, relative humidity, rainfall and sunshine hour recorded by the Meteorology Center, Dhaka during the period of the experiment have been presented in Appendix III.

3.4. Conditions of the laboratory room

The temperature and relative humidity of the laboratory room were recorded daily basis during the study period with a digital Thermo Hygrometer (TERMO, TFA, Germany). The average minimum and maximum temperature during the study period of the culture room were 18.2^{o}C to 32.4^{o}C, respectively and the average minimum and maximum relative humidity was 56% and 81%, respectively.

3.5. Experimental Materials

3.5.1. Plant materials

Thirteen Bangladeshi wheat varieties (Table 1) released by Bangladesh Agricultural Institute (BARI) were collected and used in the laboratory experiments. *Raphanus sativus* L. (Radish), *Lactuca sativa* L. (Lettuce), *Chenopodium album* L. (Bathua), *Amaranthus viridis* L. (Shaknote) were also collected from the fields of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh and used as receiver plants since *R. sativus* and *L. sativa* are used as model plants for allelopathy bioassay while *C. album* and *A. viridis* are important associated wheat weeds.

Table 1. Lists of wheat varieties along with some salient features used in the experiment

Sl. No.	Wheat varieties	Releasing year	Plant height (cm)	Yield (t ha^{-1})	Life span (days)
1	BARI Gom 21	2000	90-100	3.6-5.0	105-110
2	BARI Gom 22	2005	90-105	3.6-4.8	105-110
3	BARI Gom 23	2005	95-105	4.3-5.0	100-112
4	BARI Gom 24	2005	95-100	3.5-5.1	100-110
5	BARI Gom 25	2010	95-100	3.6-4.6	102-110
6	BARI Gom 26	2010	92-96	3.5-4.5	104-110
7	BARI Gom 27	2012	95-100	3.5-4.5	105-110
8	BARI Gom 28	2012	95-100	4.0-5.5	102-108
9	BARI Gom 29	2014	92-96	4.0-5.0	105-110
10	BARI Gom 30	2014	95-100	4.5-5.5	100-105
11	BARI Gom 31	2017	95-100	4.5-5.0	105-109
12	BARI Gom 32	2017	100-110	4.6-5.0	105-112
13	BARI Gom 33	2017	105-110	4.0-5.0	105-110

3.5.2. Supporting Materials

Petri dishes, Beakers, Filter papers, Phosphate buffer solution**,** distilled water bottle, micropipette, growth chamber, forceps, Scale, etc. were used as supporting materials.

3.6. Experimental Methods

In the experiment, the donor receiver bioassay method was used to select some possible allelopathic varieties as described by Masum *et al.* (2016). Correlation of field performance of wheat in terms of weed control with *in vitro* screening was done as described by Masum *et al.* (2020).

3.6.1. Donor Receiver Bioassay

Wheat seeds were transferred onto moistened filter paper in Petri dishes (9 cm) followed by transferring to a growth chamber. The uniform germinating wheat seedlings were transferred to Petri dishes (ten wheat seedlings per Petri dish) that contained a sheet of filter paper moistened with 2.5 ml of 1 mM phosphate buffer (pH) and grown for an additional 48 hrs. Then ten seeds of *R. sativus* or *L. sativa* were placed onto the filter paper with the growing wheat seedlings. In the case of *C. album* or *A. viridis*, the seeds were pre-germinated by soaking in distilled water for 36 hrs, transferred onto a Petri dish containing a sheet of moistened filter paper as described above, and then incubated in dark at 25°C for 48 hrs. Finally, the germinating seeds were placed onto the filter paper with the growing wheat seedlings. Wheat and the receiver species were allowed to grow for 48 hrs before the growth measurements. The shoot (hypocotyls and/or coleoptiles) and root lengths of *R. sativus*, *L. sativa*, *C. album,* and *A. viridis* were measured. On the other hand, controls were established by treating and incubating the receiver species by the same procedure as above, in the absence of the wheat seedlings according to Kato-Noguchi *et al.* (2002). Each experimental unit contained ten donors (wheat) seedlings and/or ten receivers (*R. sativus*, *L. sativa*, *C. album*, and *A. viridis*) seedlings.

3.6.2. Design and layout of the experiment

The experimental design for laboratory bioassay was a completely randomized design (CRD) with four replications. Eleven wheat varieties were selected including allelopathic and non-allelopathic from that laboratory test for the field study with three replications. The design used in the field experiment was a randomized complete block design (RCBD). The size of the individual plot was 3 m x 2 m and the total number of plots was 36. The blocks and unit plots were separated by 1.0 m and 0.50 m spacing, respectively (Appendix IV).

3.7. Seed collection

The seed of wheat varieties (Table 1) were collected from the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.8. Land preparation

The experimental field was opened by a tractor-driven rotavator 15 days before broadcasting. It was then plowed well to make the soil nearly ready for broadcasting. Weeds and stubble were removed and the field was leveled by repeated laddering. The experimental field was then divided into unit plots and prepared before broadcasting.

3.9. Fertilizer application

Fertilizers used in the experimental pots were urea, triple superphosphate (TSP), muriate of potash (MoP), and gypsum at the rate given value in a tabulated form. One-third of urea and the whole amount of other fertilizers were incorporated with soil at final plot preparation before broadcasting. The rest of the urea was applied in two equal splits one at 25 days after broadcasting and the other at 50 broadcasting.

Table 2. Fertilizer doses applied to the field during the experiment

Fertilizers	kg ha^{-1}
Urea	220
Triple superphosphate	180
Muriate of potash	120
Gypsum	50

3.10. Seed broadcasting technique

The seeds of wheat varieties were broadcasted in the respected plots on 19 November 2018. About 70g (140 kg ha^{-1}) of each variety of wheat seeds were broadcasted in each plot which was treated with Provax-200 WP an effective seed treating fungicide consisting of Carboxin and Thiramon.

3.11. Intercultural operations

3.11.1. Irrigation

The first irrigation was applied at the crown root initiation stage i.e., after three weeks of sowing. The subsequent irrigation was applied at 40and 60 days after broadcasting.

3.11.2. Weeding

No weeding was done in any plot at all. Weeds of each plot were allowed to grow and collected to take oven-dry weight after the critical period of weed competition (one-third period of crop life).

3.11.3. Plant protection measure

There were negligible infestations of insect pests during the crop growth period. Yet to keep the crop growth normal, Basudin was applied at tillering stage at the rate of 17 kg ha^{-1} while Diazinon 60 EC @ 850 ml ha^{-1} was applied. Moreover, the plots were protected by netting to prevent birds attack.

3.12. General observation of the experimental plots

Observations were made regularly and the plants looked normal green. No Lodging was observed at any stage. The maximum tillering, panicle initiation and flowering stages were not uniform.

3.13. Collection of data

Data were recorded on the following parameters:

3.13.1. *In vitro* germination parameters

- Shoot and root length of receiver plant
- Inhibition
- Germination inhibition of receiver plants
- Speed of germination of receiver plants
- Coefficient of the rate of germination of receiver plants

3.13.2. *In vivo* weed parameters

- Weed density after 15 DAS at 10 days interval up to maximum tillering
- Relative density
- Above-ground dry matter weight of weed plot^{-1} after 30 days of broadcasting
- Weed control efficiency (WCE)
- Growth stage of test weeds
- Simpson diversity index (SDI)

3.13.3. *In vivo* crop growth parameters

- Plant height from 30 days at 30 days interval up to harvest
- Tiller no. hill^{-1} from 30 days at 30 days interval up to harvest

3.13.4. *In vivo* yield contributing parameter

- Number of effective tillers hill $^{-1}$
- Spike length
- Spikelets Spike^{-1}
- 1000-seeds weight
- Grain yield
- Straw yield
- Biological yield
- Harvest index

3.14. Procedure of sampling germination parameter

3.14.1. Shoot and root length of receiver plant

Shoot and root length were measured by a scale of all receiver seedlings.

3.14.2. Inhibition

Percentage inhibition was determined by the following formula (Lin *et al*., 2004).

$$\text{Inhibition} = \frac{\text{Control plant length} - \text{Plant length infested with wheat}}{\text{Control plant length}} \times 100$$

3.14.3. Germination inhibition of receiver plants

Germination inhibition (%) of the receiver plant was measured by the following formula (Othman *et al*., 2006).

$$\text{Germination Inhibition} = \left(1 - \frac{\text{Germinated seed with wheat}}{\text{Germinated seed in control}}\right) \times 100$$

3.14.4. Speed of germination of receiver plant

The speed of germination was calculated by the following formula given by Gairola *et al.* (2011).

Speed of germination= $N_1/D_1+N_2/D_2+N_3/D_3+\ldots\ldots\ldots N_n/D_d$

Where, N = number of germinated seeds, D= number of days.

3.14.5. Coefficient of the rate of germination of receiver plant

The coefficient of the rate of germination of the receiver plant was measured by the following formula (Al-Mudaris, 1998).

$$CRG = \frac{(N1+N2+.......+Nn)}{(N1T1)+(N2T2)+.......(NnTt)} \times 100$$

Where, N_1= Number of germinated seeds on time T_1, N_2= Number of germinated seeds on time $T_{2,}$ and N_n= Number of germinated seeds on time T_n.

3.15. Procedure of sampling for weed parameters

3.15.1. Weed density

Data on different weed species were recorded at 15, 25 and 35 days after sowing. Observations on weed density were recorded using the quadrate method as described by Pound and Clements (1998).

$$\text{Weed density} = \frac{\text{Total number of weeds}}{\text{Total surveyed area}}$$

3.15.2. Weed Relative Density

The frequency of different weeds was determined and the density of each species was calculated according to Odum (1971). Weeds inside the quadrate measuring 1m x 1m were identified and counted. The species were identified with the help of ‘Bangladesher Agacha Parichiti’ (Karim and Kabir, 1995) and ‘Major Weeds of the Philippines’ (Moody *et al.*, 1984).

$$\text{Relative Density} = \frac{\text{Density of each species}}{\text{Total density of all weed species}} \times 100$$

3.15.3. Above ground dry matter weight of weed

The weeds were uprooted carefully. The uprooted weeds were washed thoroughly in clean water and dried first in the sun for two days and thereafter in an electric oven for 48 hours at 80°C. The weight of the dried sample was taken and the average data were expressed as weed dry weight (g m^{-2}).

3.15.4. Weed control efficiency (WCE)

Weed control efficiency was calculated by using the formula suggested by Mani *et al.* (1973).

$$WCE = \frac{DWC - DWT}{DWC} \times 100$$

Where DWC = dry weight of weeds from control plots (weedy plots) and DWT = dry weight of weeds in treated plots.

3.15.5. Weed growth stage

After 50% flowering, an abundance of targeted weed species was measured by counting against each variety. Each species of weeds is also evaluated based on their stage of development as juvenile (1), vegetative (2), flowering (3), and mature stage (4).

3.15.6. Simpson's diversity index (SDI)

Weed diversity and frequency were summarized using Simpson's Diversity Index (Simpson, 1949). SDI is used to quantify biodiversity in ecological studies.

It takes into account the number of species present, as well as the abundance of each species:

$$SDI = 1 - \sum n \frac{(n-1)}{N(N-1)}$$

Where n is the total number of plants of a particular species and N is the total number of all weed species.

SDI values (%) for the eleven wheat varieties used in the field experiment were correlated with the inhibition index from the laboratory bioassay.

3.16. Procedure of sampling for growth study during the crop growth period

3.16.1. Plant height

The height of the wheat plants was recorded from 30 days after broadcasting at 30 days intervals up to harvest, from the soil level to the apex of the leaf or spike of 5 random plants. The average was considered as the height of the plant for each plot.

3.16.2. Tiller no. hill^{-1}

The total tiller number was taken from 30 DAS at 30 days intervals up to harvest. The average number of tillers of five plants was considered as the total tiller no plant^{-1}.

3.17. Procedure of measuring yield and yield contributing parameter

3.17.1. Number of effective tillers hill^{-1}

The panicles which had at least one grain was considered as an effective tiller. The number of effective tillers m^{-2} was counted from 30 DAS at 15 days intervals up to 60 DAS. The average number of effective tillers of five hills was considered as the total effective tiller no hill^{-1}.

3.17.2. Spike length

Spike length was recorded from the basal nodes of the rachis to the apex of each spike.

3.17.3. Spikelet spike^{-1}

Grains of 5 randomly selected spikes of each replication were counted and then the average number of grains for each spike was determined.

3.17.4. 1000-grain weight

One thousand clean sun-dried grains were counted from the seed stock obtained from the sample plants and weighed by using an electronic balance.

3.17.5. Grain and Straw yield

An area of 1.0 m^2 was harvested for yield measurement. The crop of each plot was bundled separately, tagged properly, and brought to the threshing floor. The bundles were dried in the open sunshine, threshed, and then grains were cleaned. The grain and straw weights for each plot were recorded after proper drying in the sun and converted to t ha^{-1}.

3.17.6. Biological yield

Biological yield was calculated by using the following formula:

$$\text{Biological yield} = \text{Grain yield} + \text{straw yield}$$

3.17.7. Harvest index

It denotes the ratio of economic yield to biological yield and was calculated following the formula of Gardner *et al.* (1985). It was calculated by using the following formula:

$$\text{Harvest index (HI)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

3.18. Statistical analysis

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program Statistix 10 and the mean differences were adjusted by the Least Significance Difference (LSD) test at a 5% level of significance.

CHAPTER 4

RESULTS AND DISCUSSION

This chapter comprises a presentation and discussion of the results obtained from the study to screen out allelopathic potential Bangladeshi wheat (*Triticum aestivum*) varieties. To strengthen the discussion, information is provided in the form of tables and graphs and discussed under the following subheadings.

4.1. Laboratory Study (Donor-Receiver Bioassay)

4.1.1. Inhibition

Significant differences in growth inhibition were observed among wheat varieties in donor receiver bioassay on test plants (Table 3).

Out of 13 Bangladeshi wheat varieties, the highest level of inhibition by the BARI Gom 21 variety resulted in maximum inhibition of *Chenopodium album* root growth (81%), followed by BARI Gom 25 (64%), BARI Gom 28 (57%). However, in the case of shoot of *C. album*, BARI Gom 27 showed maximum inhibition (49%) followed by BARI Gom 26 (44%), BARI Gom 25 (33%).

Among the tested varieties, BARI Gom 21 (52%) demonstrated the highest inhibitory effect on *Raphanus sativus* root but the shoot growth was inhibited by BARI Gom 25 (67%). The variety BARI Gom 22 (32%) gave the second-highest inhibitory effect on root and BARI Gom 21 (61%) on the shoot of *R. sativus* while BARI Gom 30 (-48% inhibition in root) gave the stimulating effect on *R. sativus*.

Among the test varieties, only BARI Gom 30 (46%) and BARI Gom 21 (42%) showed more than 40% growth inhibition on *Amaranthus viridis* root. The highest level of shoot inhibition in *A. viridis* was observed from BARI Gom 25 (53%).

BARI Gom 21 (57%) and BARI Gom 26 (65%) demonstrated more than 50% growth inhibition of *L. sativa* roots. Few of varieties (3) exhibited 40 to 50% inhibition of *L. sativa* roots. Interestingly, some varieties like BARI Gom 29 (-4% inhibition), BARI Gom 31 (-10% inhibition) stimulated the root growth of *L.*

sativa. Growth inhibition of *L. sativa* root was relatively higher than *L. sativa* shoot. The highest (24%) *L. sativa* shoot inhibition was observed from BARI Gom 28.

Table 3. Allelopathic potential of wheat varieties in donor-receiver bioassay under laboratory condition

Variety	Inhibition (%)							
	C. album		***R. sativus***		***A. viridis***		***L. sativa***	
	Root	**Shoot**	**Root**	**Shoot**	**Root**	**Shoot**	**Root**	**Shoot**
BARI Gom 21	81a	32.94c	52.13a	61.14b	42.48b	41.50c	56.65b	6.71d
BARI Gom 22	30.5f	33.88c	32.31b	52.65de	34.29d	32.42e	47.27c	3.45fg
BARI Gom 23	46.98d	36.18c	-29.55j	49.56ef	24.35f	40.10c	8.60h	12.22c
BARI Gom 24	37.44e	24.1d	9.14e	59.65bc	23.2f	26.97f	38.66e	2.21g
BARI Gom 25	64.20b	33.12c	26.10c	67.40a	14.22h	52.60a	44.13d	12.97c
BARI Gom 26	30.81f	43.62b	4.14f	56.18cd	-30.48j	23.36g	65.23a	4.82ef
BARI Gom 27	46.05d	49.24a	18.39d	46.78fg	18.43g	33.85de	3.91i	12.81c
BARI Gom 28	56.61c	22.83d	-1.92g	55.06d	31.48e	11.19h	17.84g	23.59a
BARI Gom 29	34.75ef	21.37d	-25.58i	47.54fg	39.03c	45.31b	-4.18j	7.27d
BARI Gom 30	49.32d	32.24c	-48.20k	52.56de	45.51a	45.88b	48.54c	14.77b
BARI Gom 31	49.32g	35.68c	32.54b	45.43g	12.76h	36.26d	-9.97k	6.24de
BARI Gom 32	45.87d	34.39c	32.46b	59.70bc	18.60g	2.05i	9.18h	6.29de
BARI Gom 33	46.14d	36.34c	-21.07h	36.41h	-8.03i	41.74c	35.45f	6.63fg
LSD $_{(0.05)}$	**5.47**	**2.26**	**2.76**	**4.07**	**1.82**	**2.93**	**3.08**	**1.58**
CV (%)	**8.42**	**8.88**	**30.97**	**5.36**	**6.21**	**6.16**	**7.75**	**12.24**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Similar significant differences in growth inhibition were observed among wheat varieties in equal compartment agar method bioassay test on littleseed canarygrass (*Phalaris minor*) by Kashif *et al.* (2015)**.** They stated that wheat cultivars had differential allelopathic inhibition activity against littleseed canarygrass through the production of phenolic compounds. Maximum inhibition in root length (54%), shoot length (59%) of littleseed canarygrass was found when grown in association with wheat cv. Shafaq-06.

From the Figure 1, it is also observed that across all the wheat varieties, *Chenopodium album* (39%) was the most inhibited when grown with wheat seedlings, followed by *Raphanus sativus* (30%), *Amaranthus viridis* (27%), and *Lactuca sativa* (18%).

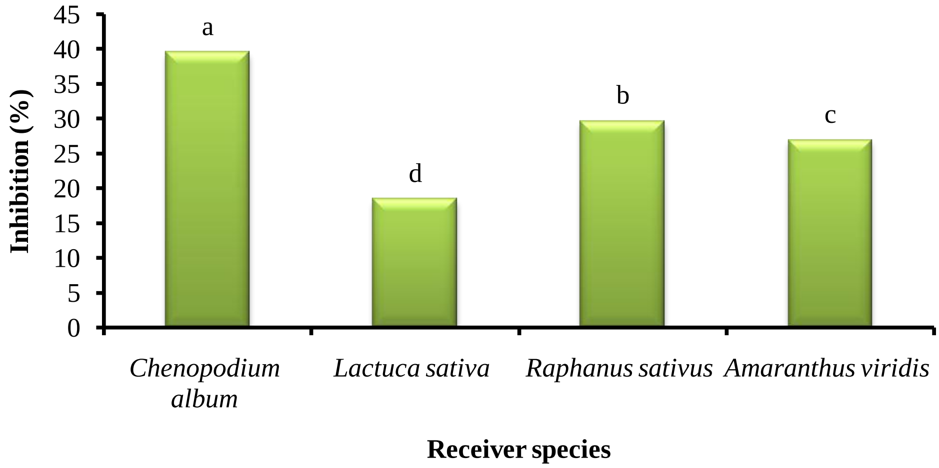


Figure 1. Average inhibition on receiver species due to infestation with irrespective of wheat varieties.

Based on donor-receiver bioassay results, the highest average inhibition on test plants and weeds was from BARI Gom 21 (47%) followed by BARI Gom 25 (39%) and BARI Gom 22 (33%) (Figure 2).

A similar result was found in terms of rice allelopathy by Masum *et al.* (2016). Across all the rice varieties, they found that radish (21%) was the most inhibited grown along with rice, followed by lettuce (17%), cress (15%), barnyardgrass (14%), and jungle rice (10%) based on donor-receiver bioassay and ECAM bioassay results. The highest average inhibition on test plants and weeds was from Boterswar (46%) followed by Goria (44%), Biron (37%), and Kartiksail (36%).

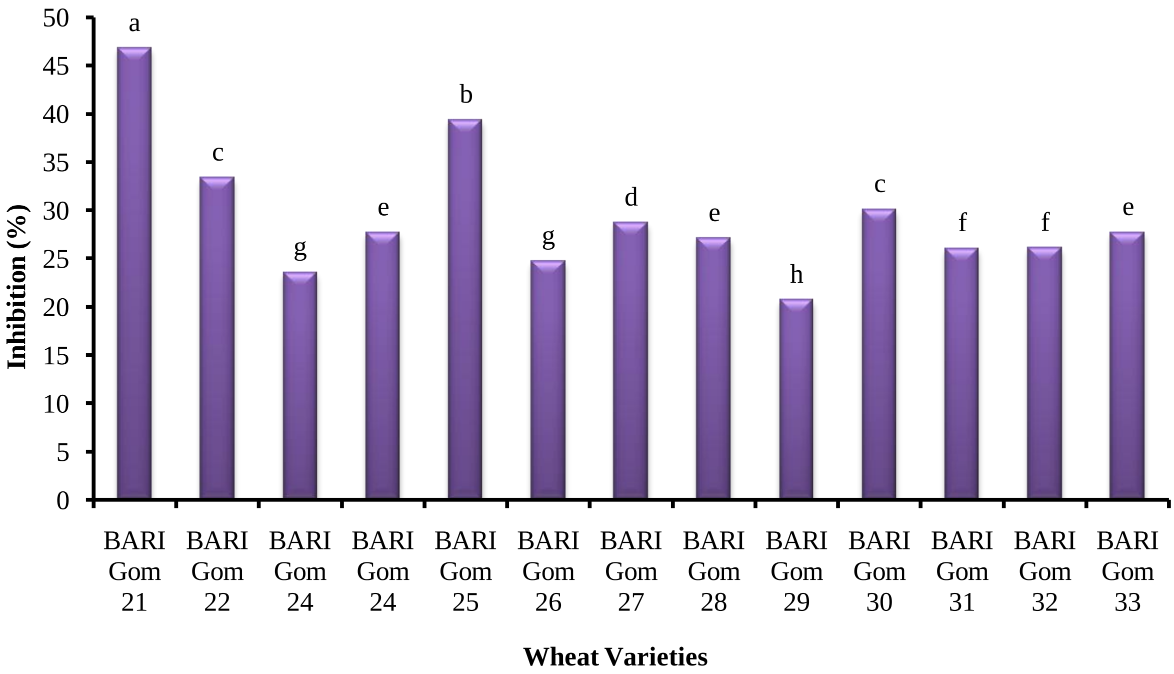


Figure 2. Average inhibition on irrespective of receiver species by tested wheat varieties from donor-receiver bioassay test.

However, in all receiver species, inhibitions on root growth were greater than those on shoot growth. That result was similar to the report of Olofsdotter and Navarez (1996), Kim and Shin (1998) who reported that allelopathic crop varieties strongly inhibited the root growth rather than the shoot of weeds.

4.1.2. Germination inhibition of receiver plant

Although the germination percentage of receiver plant seeds showed non-significant variation during growing with different wheat varieties, only *Raphanus sativus* showed a significant difference (Table 4). BARI Gom 21 caused maximum germination inhibition (7.5%) over *R. sativus*, where BARI Gom 22 (2.5%), BARI Gom 25 (2.5%), BARI Gom 26 (2.5%), BARI Gom 27 (2.5%), BARI Gom 28 (2.5%), BARI Gom 29 (2.5%) and BARI Gom 24 (5%) showed the statistically similar germination inhibition percentage over receiver *R. sativus*.

Table 4. Germination inhibition percentage of different receiver species in donor-receiver bioassay under laboratory condition

Variety	Germination (%)			
	C. album	***R. sativus***	***A. viridis***	***L. sativa***
BARI Gom 21	5	7.5a	2.5	2.5
BARI Gom 22	0	2.5ab	2.5	0
BARI Gom 23	0	0b	2.5	0
BARI Gom 24	0	5ab	0	2.5
BARI Gom 25	2.5	2.5ab	2.5	5
BARI Gom 26	5	2.5 ab	2.5	0
BARI Gom 27	2.5	2.5 ab	5	0
BARI Gom 28	0	2.5 ab	0	2.5
BARI Gom 29	0	2.5 ab	2.5	0
BARI Gom 30	0	0b	2.5	0
BARI Gom 31	2.5	0b	2.5	2.5
BARI Gom 32	0	0b	0	0
BARI Gom 33	0	0b	2.5	0
LSD $_{(0.05)}$	**NS**	**6.57**	**NS**	**NS**
CV (%)	**4.06**	**4.70**	**5.11**	**3.97**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

4.1.3. Speed of germination of receiver plant

The calculated indices are provided in Table 5. Different wheat varieties significantly affected the germination speed of the receiver plants. In the case of *C. album*, BARI Gom 21 (5.35) showed the lowest germination speed followed by BARI Gom 23 (5.50) where BARI Gom 33 (7.66) showed the highest. BARI Gom 21 also demonstrated the lowest germination speed in the case of *R. sativus* (4.00), *A. viridis* (4.32), and *L. sativa* (4.83). The highest germination speed was observed by BARI Gom 25 (7.00), BARI Gom 33 (5.83), BARI Gom 23 (6.66) in terms of *R. sativus, A. viridis,* and *L. sativa*, respectively (Table 5).

Table 5. Speed of germination of different receiver species in donor-receiver bioassay under laboratory condition

Variety	Speed of germination			
	C. album	*R. sativus*	*A. viridis*	*L. sativa*
BARI Gom 21	5.35i	4.00j	4.32g	4.83i
BARI Gom 22	6.00f	4.83h	5.83a	5.66e
BARI Gom 23	5.50hi	5.50f	5.67b	6.66a
BARI Gom 24	6.83e	6.00c	5.67b	6.50b
BARI Gom 25	5.67gh	7.00a	5.83a	5.66e
BARI Gom 26	5.83fg	5.83d	5.17d	5.33g
BARI Gom 27	5.75g	5.67e	5.83a	5.99d
BARI Gom 28	6.83e	4.67i	4.83e	5.49f
BARI Gom 29	6.00f	5.16g	5.83a	6.50b
BARI Gom 30	7.83c	5.83d	5.33c	5.66e
BARI Gom 31	8.49a	6.17b	4.66f	6.33
BARI Gom 32	8.18b	5.67e	5.67b	5.50f
BARI Gom 33	7.66d	5.67e	5.83a	5.17h
LSD $_{(0.05)}$	**0.17**	**0.09**	**0.05**	**0.07**
CV (%)	**1.83**	**1.17**	**0.71**	**0.91**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

4.1.4. Coefficient of velocity of germination of receiver plant

The coefficient of velocity of germination of receiver plants was significantly influenced by different wheat varieties (Table 6). The minimum coefficient of velocity of germination was recorded by *C. album* is 1.98 against BARI Gom 25 however maximum was recorded as 2.52 against BARI Gom 31.

R. sativus perform a lower coefficient of velocity of germination against BARI Gom 28 (1.92) and higher against BARI Gom 24 (2.39).

A. viridis was found as the lower coefficient of the velocity of germinating against BARI Gom 21 (1.92), BARI Gom 28 (1.93), and BARI Gom 26 (1.93). The highest coefficient of velocity of germination was found against BARI Gom 33 (2.21).

The lowest coefficient of velocity of germination was observed in *L. sativa* by BARI Gom 33 (1.93) where the highest was listed by BARI Gom 23 (2.19).

Table 6. Coefficient of velocity of germination of different receiver species in donor-receiver bioassay under laboratory condition

Variety	Coefficient of velocity of germination			
	C. album	***R. sativus***	***A. viridis***	***L. sativa***
BARI Gom 21	2.22e	2.03e	1.92e	1.97f
BARI Gom 22	2.19f	2.03e	2.03d	2.15b
BARI Gom 23	2.02i	1.96f	2.16b	2.19a
BARI Gom 24	2.25d	2.39a	2.08c	2.14c
BARI Gom 25	1.98j	2.34b	2.08c	1.97f
BARI Gom 26	2.02i	2.15c	1.93e	1.97f
BARI Gom 27	2.08h	1.96f	2.03d	2.08d
BARI Gom 28	2.25d	1.92g	1.93e	2.03e
BARI Gom 29	2.14g	2.08d	2.08c	2.14c
BARI Gom 30	2.37b	2.03e	2.03d	2.13c
BARI Gom 31	2.52a	2.03e	2.08c	2.08d
BARI Gom 32	2.37b	2.08d	2.08c	2.03e
BARI Gom 33	2.31c	1.96f	2.21a	1.93g
LSD $_{(0.05)}$	**0.013**	**0.029**	**0.015**	**0.013**
CV (%)	**0.41**	**1.00**	**0.52**	**0.46**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

A similar type of significant differences in germination parameter was observed among rice varieties by Masum *et al.* (2016) where they found some allelochemicals delayed *Echinochloa crus-galli* germination at concentrations of 1000, 100, and 10 μM and significantly affected the germination index, speed of and coefficient of germination rate.

4.2. Weed parameters

4.2.1. Weed density

Weed density is no weeding plots at 15, 25, and 35 days after broadcasting were more or less similar for different wheat varieties (Table 7). However, except weedy plot, at 15 days after broadcasting the lowest weed density was found in BARI Gom 21 (14.66 m^{-2}) and highest in BARI Gom 30 raised plot (32.33 m^{-2}). Statistically similar data was found in both cases.

At 25 days after broadcasting, weed density was found minimum in BARI Gom 21 (28.33 m^{-2}) whereas the maximum weed density was found in BARI Gom 28 (39.00 m^{-2}). The lowest weed density was also found in BARI Gom 21 (33.33 m^{-2}) plot after 35 days after broadcasting. Other than the weedy plot, the highest weed density was found in BARI Gom 22 plot (59.33 m^{-2}).

Table 7. Weed density in different wheat varieties raised plots at different days after sowing (DAS)

Variety	**Weed density (no.m^{-2})**		
	15 DAS	**25 DAS**	**35 DAS**
BARI Gom 21	14.66f	28.33d	35.33d
BARI Gom 22	17.33ef	33.00b-d	59.33b
BARI Gom 23	22.33c-f	29.33d	35.33d
BARI Gom 24	20.66d-f	32.66b-d	54.00bc
BARI Gom 25	19.66d-f	35.00b-d	44.66cd
BARI Gom 28	27.33b-d	39.00b	53.33bc
BARI Gom 29	23..33c-d	3066d	44.33cd
BARI Gom 30	32.33b	28.66d	46.33cd
BARI Gom 31	28.66bc	31.00cd	37.66d
BARI Gom 32	22.33c-f	30.33d	54.33bc
BARI Gom 33	21.66c-f	38.00bc	51.66bc
Weedy plot	41.66a	62.66a	91.33a
LSD $_{(0.05)}$	**7.93**	**7.05**	**11.28**
CV (%)	**19.26**	**11.94**	**13.16**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

A similar result was found by Hossain *et al.* (2010) who recorded weed density is no weeding plots at 34 and 56 DAS. However, at 34 DAS the highest weed density was found in Shatabdi followed by BAW 1059 and the lowest in Bijoy. At 56 DAS, weed density was found maximum in BAW 1064, whereas the minimum weed density was found in Bijoy and Sourav, respectively.

4.2.2. Relative Weed Density (%)

The dominant weed species found in the experimental field were *Chenopodium album, Cynodon dactylon, Eleusine indica, Echinochloa colona, Solanum carolinense, Raphanus raphanistruma, Lindernia procumbens, Vicia sativa, Amaranthus viridis, Argemone mexicana, Corchorus acutangulus, Portulaca olerace, Nicotiana plumbaginifolia, Physalis heterophylla, Alternanthera philoxeroides, Heliotropium Indicum, Cyperus rotundus.*

Of these, many species were under the family Poaceae, some species under Solanaceae and Amaranthaceae. Other species are Compositae, Cyperaceae, Chenopodiaceae, Brassicaceae, Boraginaceae, Portulacaceae. When classified based on habit, 30% of weeds were under grass, 65% under shrubs, and 5% under sedge. Similar findings were also reported by Hossain *et al.* (2009).

The relative density of some major weed species found in wheat plots during the experiment is showed in table 8. Interestingly some major weed species of wheat including *C. album and A. viridis* were not found in BARI Gom 21 and BARI Gom 30 raised plots.

Table 8. Relative weed density in different plots of wheat and weedy plot

Variety	Relative Weed Density (%)						
	C. album	***C. dactylon***	***E. indica***	***S. carolinense***	***L. procumbens***	***A. viridis***	***E. colona***
BARI Gom 21	0.00e	12.24a	31.11f	2.85bc	2.85bc	9.44b-d	3.78bc
BARI Gom 22	7.17b-d	12.29a	52.27a	2.01c	0.49c	5.59e	2.60c
BARI Gom 23	9.46ab	11.51ab	32.48ef	4.25a-c	7.88a	8.66c-e	5.72ab
BARI Gom 24	5.55d	12.38a	50.98ab	3.89a-c	4.63a-c	8.07c-e	3.04c
BARI Gom 25	10.61a	12.23a	38.32c-f	4.52a-c	6.08ab	13.47a	3.75bc
BARI Gom 28	5.95cd	10.05ab	50.26ab	3.58a-c	4.8sa-c	8.80b-e	2.83c
BARI Gom 29	7.57a-d	9.76ab	34.41d-f	4.46a-c	4.46a-c	11.95ab	2.98c
BARI Gom 30	0.00e	10.40ab	32.51ef	2.83bc	3.84a-c	13.11a	6.63a
BARI Gom 31	5.39d	12.37a	41.63b-e	6.16a	5.24ab	9.70bc	2.67c
BARI Gom 32	9.18a-c	8.53ab	42.29b-d	4.91ab	3.77a-c	6.11e	3.61c
BARI Gom 33	8.99a-c	7.13b	39.65c-f	3.24bc	4.63abc	6.42de	3.19c
Weedy plot	5.32d	12.59a	45.96a-c	3.66abc	5.90ab	6.08e	5.84a
LSD $_{(0.05)}$	**3.36**	**4.78**	**9.50**	**2.59**	**4.53**	**3.24**	**2.05**
CV (%)	**31.69**	**25.72**	**13.69**	**39.59**	**58.76**	**21.40**	**31.13**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

4.2.3. Above ground dry matter weight of weed

In the field experiment, BARI Gom 21 raised plot was less infested by weed and showed the lowest (12.02 g m^{-2}) weed dry matter (Table 9), followed by BARI Gom 23, BARI Gom 29, and BARI Gom 28 raised plot showed 14.65, 16.33 and 17.17 g m^{-2}, respectively as statistically similar. On the contrary, the highest weed dry matter was recorded in BARI Gom 22 (29.44 g m^{-2}) and BARI Gom 24 (28.20 g m^{-2}).

A similar phenomenon was observed by Oad *et al.* (2007) where the maximum weed biomass 680 g m^{-2} was recorded in the treatment having wheat- *Avena fatua* and nonsignificant values of wheat-*Phalaris minor,* Wheat-*C. album,* and Wheat-Mmixed weeds grown at the ratio of 2:1 (wheat-weeds). The minimum weed biomass was exhibited in the area of wheat-natural weeds.

4.2.4. Weed control efficiency (%)

BARI Gom 21 showed the maximum weed control efficiency (86%) during the field experiment. However, statistically similar result was found by BARI Gom 23 (84%), BARI Gom 28 (81%) and BARI Gom 29 (81%) (Table 9).

Table 9. Above-ground dry matter weight of weed plot^{-1} and weed control efficiency after 30 DAS

Wheat Variety	Weed dry matter weight (g m^{-2})	Weed control efficiency (%)
BARI Gom 21	12.02g	86.47a
BARI Gom 22	29.44b	66.80e
BARI Gom 23	14.65fg	83.67ab
BARI Gom 24	28.20bc	68.08e
BARI Gom 25	22.32d	74.55d
BARI Gom 28	17.17d-g	80.59a-c
BARI Gom 29	16.43e-g	81.32a-c
BARI Gom 30	18.23 d-f	79.30b-d
BARI Gom 31	22.77cd	74.52d
BARI Gom 32	19.87d-f	77.58cd
BARI Gom 33	20.93de	76.89cd
Weedy plot	88.84a	
LSD $_{0.05}$	**5.63**	**5.92**
CV (%)	**12.85**	**4.50**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Weedy plot was found as the maximum value of weed dry matter weight (88.84 gm^{-2}). The result supported the statement of Rahman *et al.* (2012) who noted that weed population and weed dry weight showed the highest result in fallow land with no biomass application.

The weed control efficiency data supported the statement of Sultana *et al.* (2012) who observed that weed control efficiency significantly varies in different varieties.

4.2.5. Weed growth stage

An abundance of targeted weed species was measured by counting against each variety after 50% flowering of wheat plants. Data of each species of weeds were recorded based on their stage of development as juvenile (1), vegetative (2), flowering (3), and mature stage (4) (Table 10). It was recorded that a major portion of the weeds was found in their vegetative stage. Several weeds were at the stage of flowering during recording the data. Some weeds were found in the mature stage at 50% flowering of wheat plants.

Table 10. Growth stage of different weeds found in different wheat plots during the field experiment at 50% flowering of wheat plants

Weed name	Family	Habit	Life span	Growth stage
Chenopodium album	Chenopodiaceae	Shrub	Annual	2
Cynodon dactylon	Poaceae	Grass	Perennial	2
Eleusine indica	Poaceae	Grass	Perennial	3
Solanum carolinense	Solanaceae	Shrub	Annual	3
Lindernia procumbens	Scrophulariaceae	Shrub	Annual	2
Amaranthus spp.	Amaranthaceae	Herb	Annual	4
Echinochloa colona	Poaceae	Grass	Annual	3
Raphanus raphanistruma	Brassicaceae	Herb	Perennial	2
Vicia sativa	Fabaceae	Herb	Annual	1
Corchorus acutangulus	Malvaceae	Shrub	Annual	3
Portulaca olerace	Portulacaceae	Shrub	Annual	2
Nicotiana plumbaginifolia	Solanaceae	Shrub	Perennial	2
Cyperus rotundus	Cyperaceae	Sedge	Perennial	3
Physalis heterophylla	Solanaceae	Shrub	Annual	3
Heliotropium Indicum	Boraginaceae	Shrub	Annual	4
Mimosa pudica	Fabaceae	Herb	Annual	3

Maximum number of *Chenopodium album* (69 m^{-2}) was found at vegetative stage at 50% flowering of wheat plants. Lowest number was found (7 m^{-2}) at mature stage. On the other hand, *Amaranthus* spp. was found maximum (68 m^{-2}) at mature stage and lowest (10 m^{-2}) at juvenile stage (Figure 3).

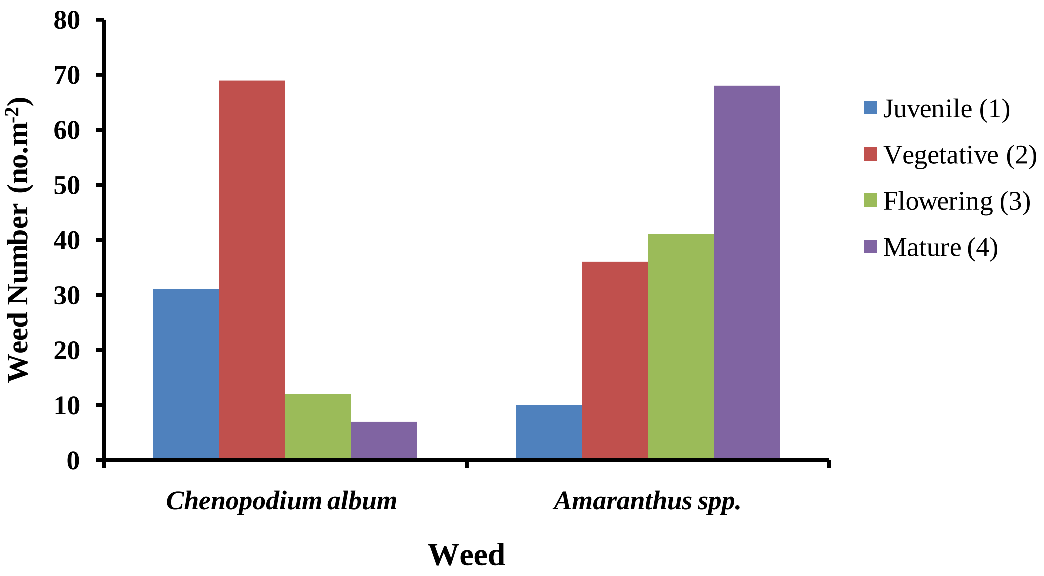


Figure 3. Number of two major weeds found at their different life stages at 50% flowering of wheat plants during field experiment.

4.2.6. Simpson's Diversity Index (SDI)

To quantify biodiversity for ecological studies, number of species present in the wheat plot during the experiment as well as the abundance of each species were recorded. Data showed that BARI Gom 22 plot depicted the lowest (0.68) SDI where BARI Gom 21 depicted the maximum (0.82) (Table 11).

Younesabadi *et al.* (2019) also observed the highest Simpson diversity index in Kalaleh (0.43) and Minoo Dasht (0.4) and the lowest value of SDI in Gonbad (0.11) and Khan Bebin (0.11).

Table 11. Simpson diversity index (SDI) of different weeds found in different wheat plots during field experiment

Wheat Variety	Simpson diversity index	
	SDI	**(%)**
BARI Gom 21	0.82	82.61
BARI Gom 22	0.68	68.08
BARI Gom 23	0.75	75.25
BARI Gom 24	0.70	70.41
BARI Gom 25	0.79	79.93
BARI Gom 28	0.70	70.45
BARI Gom 29	0.79	79.49
BARI Gom 30	0.77	77.24
BARI Gom 31	0.78	78.01
BARI Gom 32	0.76	76.24
BARI Gom 33	0.74	74.69
Weedy plot	0.73	73.49

4.2.7. Correlation between SDI and inhibition index obtained from the laboratory bioassay

SDI of different wheat varieties showed positive and strong correlation with the root inhibition percentage of *Chenopodium album* obtained from laboratory bioassay. The correlation between inhibition percentage and SDI was strong (R^2 = 0.386) (Figure 4).

Masum *et al.* (2019a) recorded a significant correlation coefficient (0.87) between SDI and the root inhibition percentage from the laboratory bioassay in term of rice where they found the Boterswar variety the most allelopathic.

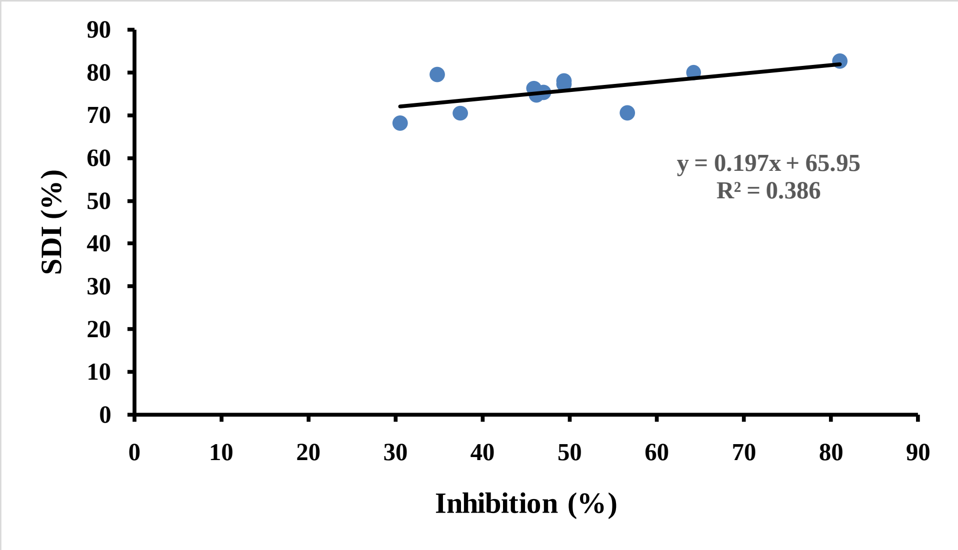


Figure 4. Correlation between SDI value and root inhibition of *Chenopodium album* obtained from the laboratory bioassay.

4.3. Crop growth parameters

4.3.1. Plant height

Plant height of different wheat plots was measured at the different growing periods starting from 30 days of broadcasting up to harvest at 30 days interval (Table 12).

Wheat varieties exhibited significant differences in plant height at different periods of growth. At 30 days of broadcasting, among the varieties, BARI Gom 22 showed significantly as the tallest plant (24.44 cm) which was statistically similar to BARI Gom 31 (24.22 cm). Significantly the shortest plants at 30 days of broadcasting are BARI Gom 33 (17.35 cm) and BARI Gom 21 (17.79 cm). BARI Gom 21 remained the shortest in both 60 days of broadcasting (32.98 cm) and at harvest (69.63 cm). BARI Gom 31 (53.63 cm) and BARI Gom 33 (84.32 cm) showed as tallest at 60 days of sowing and at harvest, respectively.

Similar results were found by Maharjan *et al.* (2007) who studied allelopathic effects of *Parthenium hysterophorus* on seed germination and seedling growth of three cereal crops *viz*., *Oryza sativa*, *Zea mays* and *Triticum aestivum*.

Table 12. Plant height at 30, 60 DAS and at harvest time in the field experiment

Variety	Plant height (cm)		
	30 DAS	**60 DAS**	**At harvest**
BARI Gom 21	17.79ef	32.98g	69.63i
BARI Gom 22	24.44a	48.98b	70.90h
BARI Gom 23	20.53c	45.03de	79.67b
BARI Gom 24	20.69c	39.69f	71.90g
BARI Gom 25	22.67b	47.76b-d	78.58c
BARI Gom 28	19.64d	45.74c-e	75.63d
BARI Gom 29	18.54e	43.00e	74.30e
BARI Gom 30	20.77c	45.55c-e	73.35f
BARI Gom 31	24.23a	53.63a	74.52e
BARI Gom 32	22.87b	48.48bc	75.77d
BARI Gom 33	17.35f	45.13de	84.32a
LSD $_{(0.05)}$	**0.83**	**3.01**	**0.56**
CV (%)	**2.36**	**3.93**	**0.44**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

4.3.2. Tillers no. hill^{-1}

Wheat varieties exerted a significant difference on the number of tillers hill^{-1} at a 5% level of significance (Table 13). The highest number of tillers hill^{-1} at 30 DAS, 60 DAS and at harvest was produced by BARI Gom 21 (4.03, 5.33, 6.33) which suppressed weed effectively. Among the varieties, BARI Gom 33 produced the lowest number of tillers hill^{-1} (1.27, 2.67, 3.20) at 30 DAS, 60 DAS and at harvest respectly.

Table 13. Tillers no. hill^{-1} at 30, 60 DAS and at harvest time in the field experiment

Variety	Tillers no. hill^{-1}		
	30 DAS	**60 DAS**	**At harvest**
BARI Gom 21	4.03a	5.33a	6.33a
BARI Gom 22	3.53ab	3.57c	3.67de
BARI Gom 23	2.40c	3.60c	4.47c
BARI Gom 24	2.60b	4.37b	5.87b
BARI Gom 25	2.07c	3.87bc	4.27c
BARI Gom 28	1.73c	3.33d	4.07cd
BARI Gom 29	2.20c	3.87bc	4.27c
BARI Gom 30	1.53d	2.97e	4.40c
BARI Gom 31	1.53d	2.67e	3.47ef
BARI Gom 32	2.20c	4.17bc	5.47b
BARI Gom 33	1.27d	2.67e	3.20f
LSD $_{(0.05)}$	**0.94**	**0.71**	**0.46**
CV (%)	**8.28**	**6.36**	**5.99**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Variable effect of variety on the number of total tillers hill^{-1} was also reported by Jaiswal and Singh (2001) who noticed that number of total tillers hill^{-1} in plants differed among the varieties. The variation in the number of total tillers hill^{-1} as assessed might be due to varietal character and/or weed infestation.

4.4. Yield contributing parameter

4.4.1. Number of effective tillers hill^{-1}

Wheat varieties exhibited a significant difference in the effective number of tillers hill^{-1} at a 5% level of significance (Table 14). Remarkably the highest number of effective tillers hill^{-1} at harvest was produced by BARI Gom 21 (5.67). Among the varieties, BARI Gom 33 produced the lowest number of tillers hill^{-1} (3.13). BARI Gom 31 (3.27) was statistically similar to BARI Gom 33 (3.13).

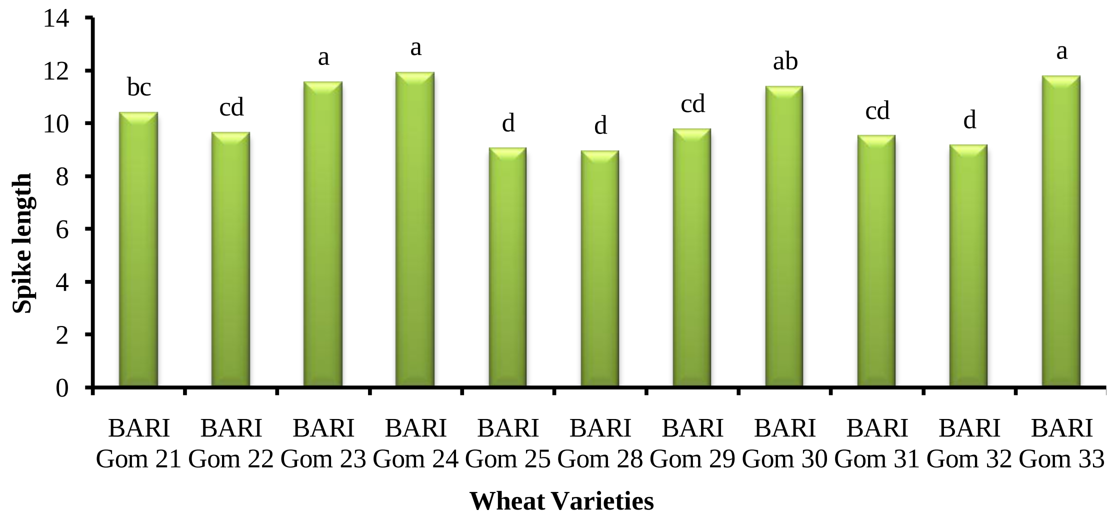
Table 14. Average effective tiller no. hill^{-1} of wheat varieties due to infested with different weed species

Wheat Variety	Number of effective tillers hill^{-1} (no.)
BARI Gom 21	5.67a
BARI Gom 22	2.93de
BARI Gom 23	3.97c
BARI Gom 24	5.03b
BARI Gom 25	4.07c
BARI Gom 28	4.00c
BARI Gom 29	4.13c
BARI Gom 30	4.20c
BARI Gom 31	3.27ef
BARI Gom 32	5.43b
BARI Gom 33	3.13f
LSD $_{(0.05)}$	**0.41**
CV (%)	**5.88**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

4.4.2. Spike length

There was a little significant variation of spike length observed for different wheat varieties. The numerically maximum spike length (15.76 cm) was found with BARI Gom 24 where BARI Gom 33 (11.78 cm), BARI Gom 23 (11.55 cm), BARI Gom 30 (11.38 cm) were statistically similar. Numerically minimum (8.94 cm) was with BARI Gom 28 (Figure 5).

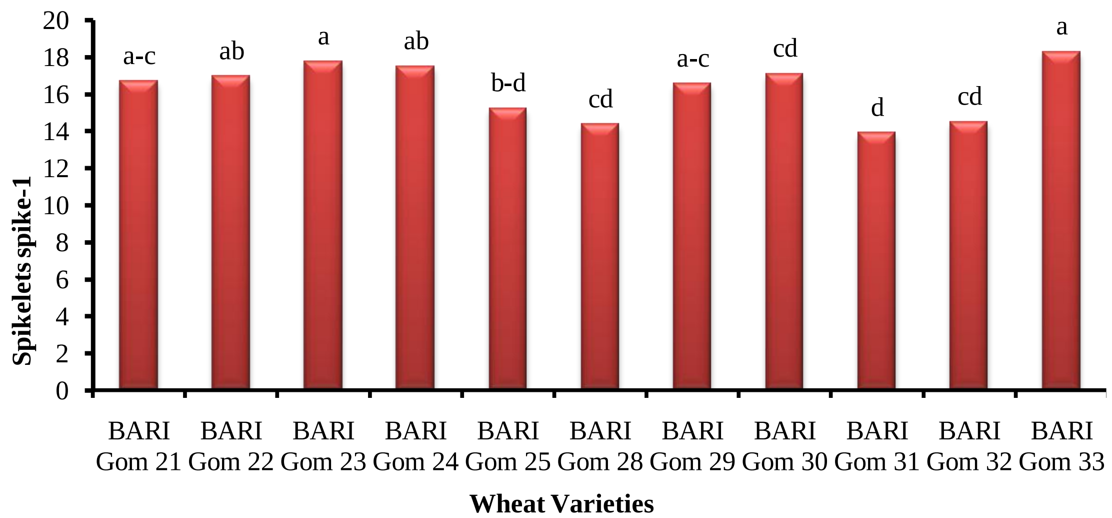


In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Figure 5. Average spike length of wheat varieties due to infestation with different weed species (LSD $_{(0.05)}$ = 1.15).

4.4.3. Spikelets spike^{-1}

Numerically maximum spikelets spike^{-1} was recorded in BARI Gom 33 (18.27) where similar statistical data were also found. Numerically minimum data was found in BARI Gom 31 (13.87) (Figure 6).



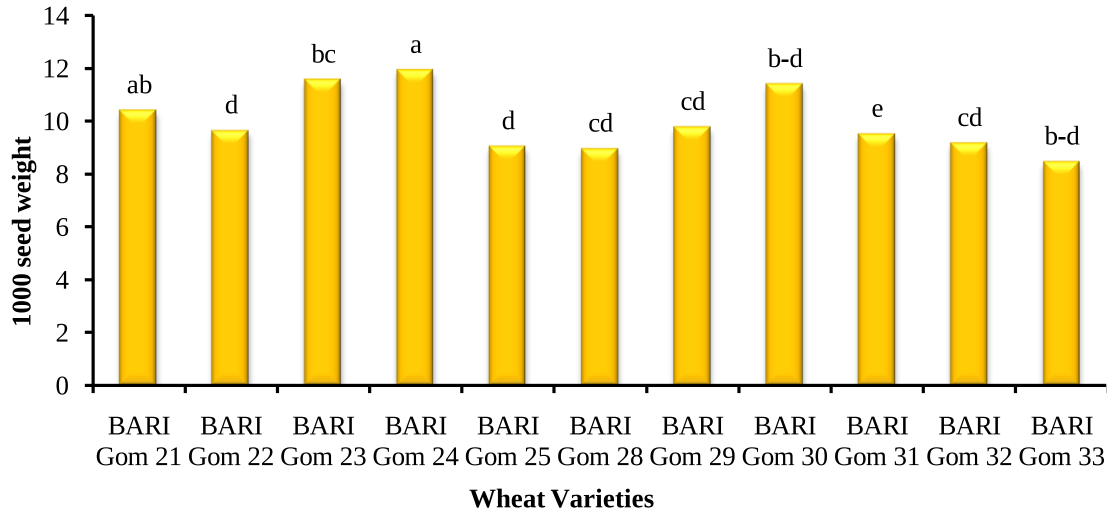
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Figure 6. Average spikelets spike^{-1} of wheat varieties due to infestation with different weed species (LSD $_{(0.05)}$ = 2.38).

4.4.4. 1000 seed weight

Varieties differed significantly for the weight of thousand grains of wheat. BARI Gom 24 (11.92 g) and BARI Gom 21 (10.39 g) produced heavier seeds than any other varieties (Figure 7). Though the minimum weight of thousand grains was recorded in BARI Gom 31 (9.50 g).

The variations in yield contributing characters of wheat due to variety were also observed by Tahir *et al.* (2009).

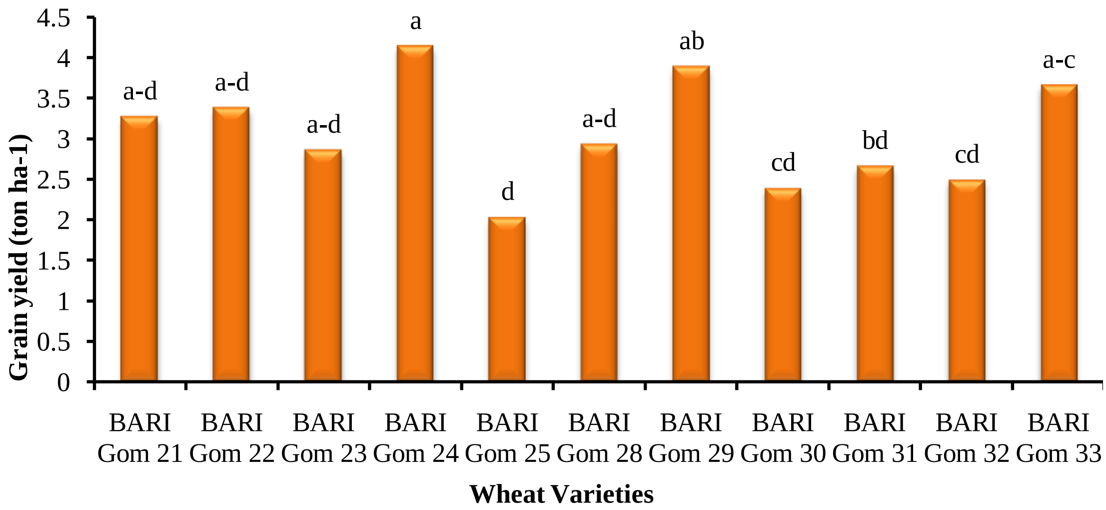


In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Figure 7. Average 1000 seed weight of wheat varieties due to infestation with different weed species (LSD $_{(0.05)}$ = 1.58).

4.4.5. Grain yield

Wheat varieties showed a significant difference in producing grain yield (Figure 8). Among the varieties, BARI Gom 24 (4.14 t ha^{-1}) showed its superiority in producing numerically the highest grain yield which was 6.42% higher than BARI Gom 29 (3.89 t ha^{-1}) and statistically similar with some other verities. The lowest grain yield (2.03 t ha^{-1}) was found in BARI Gom 25.

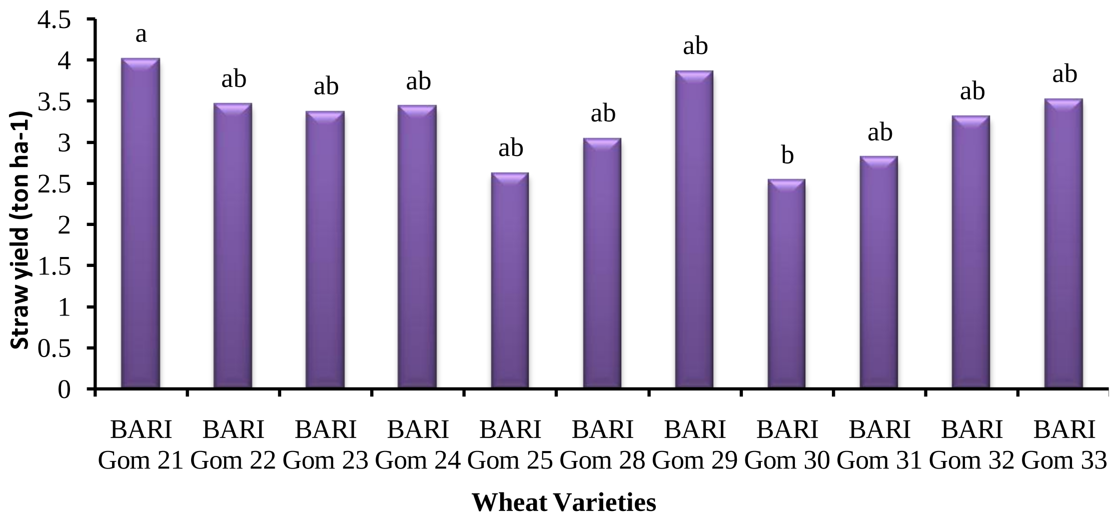


In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Figure 8. Average Grain yield of wheat varieties due to infestation with different weed species (LSD $_{(0.05)}$ = 1.39).

4.4.6. Straw yield

Straw yield was recorded as a significant difference due to varietal variations (Figure 9). BARI Gom 21 gave the highest straw yield (4.01 t ha^{-1}) and the lowest straw yield was found in BARI Gom 21 (2.52 t ha^{-1}). The differences in straw yield among the varieties might be attributed to the genetic makeup of the varieties.

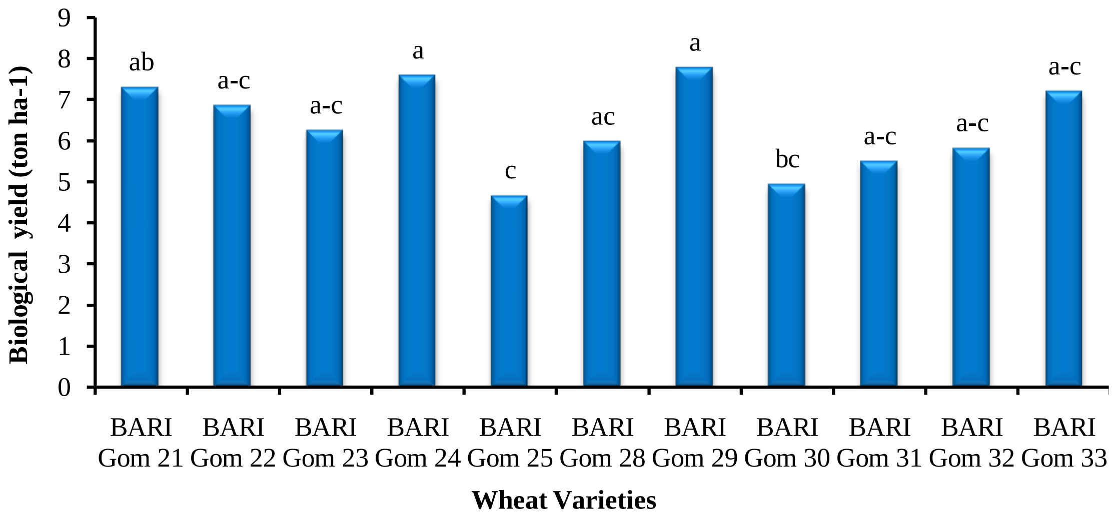


In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Figure 9. Average Straw yield of wheat varieties due to infestation with different weed species (LSD $_{(0.05)}$ = 1.46).

4.4.7. Biological yield

Significant variation in biological yield was observed due to varietals variations and it ranges from 4.65-7.76 t ha^{-1} (Figure 10). The highest and lowest biological yield was obtained from BARI Gom 29 (7.76 t ha^{-1}) and BARI Gom 25 (4.65 t ha^{-1}), respectively. The biological yield of both varieties was statistically similar to some others varieties.

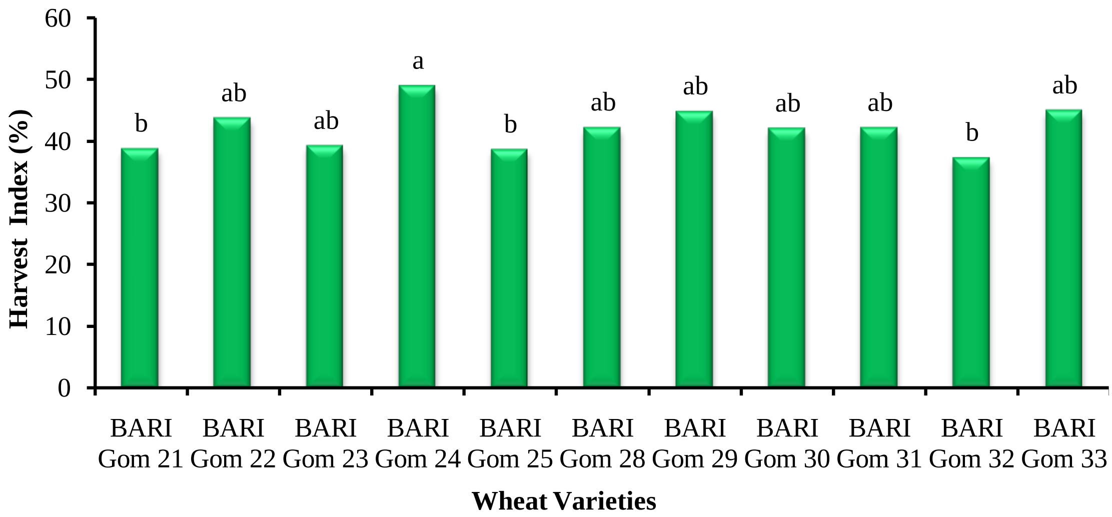


In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Figure 10. Average Biological yield of wheat varieties infested with different weed species (LSD $_{(0.05)}$ = 2.54).

4.4.8. Harvest Index (HI)

A significant difference was observed for harvest index (%) due to varietal variations (Figure 11). However, BARI Gom 24 showed the maximum harvest index (48.86%) and the minimum harvest index (38.18%) was found in BARI Gom 32. Both varieties were found statistically similar to some others varieties.



In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Figure 11. Harvest index of wheat varieties infested with different weed species (LSD $_{(0.05)}$ = 9.93).

Alam *et al.* (2003) demonstrated that wheat varieties differed significantly in 1000 grain weight, grain yield, straw yield and harvest index.

CHAPTER 5

SUMMARY AND CONCLUSION

Allelopathy governs the dynamics of plant species in different surroundings. Crops that can control weeds by root exudation of allelochemicals are receiving increased attention and there are efforts to breed allelopathic cultivars in several crops. Understanding this natural phenomenon could help to advance applications in agricultural systems. The main objectives of this research were to find out Bangladesh allelopathic wheat varieties and their significance in weed management by cultivating as the main crop or applying as residues into the soil. For establishing an alternative strategy for weed management in wheat, the phenomenon of allelopathy has been a subject of continued research for a long time.

In this research 13 wheat varieties were collected from Bangladesh Agricultural Institute to assess the allelopathic potential in the laboratory, and field experiments at the agronomy field of Sher-e-Bangla Agricultural University. Initially, the donor-receiver bioassay method was used to assess allelopathic potential varieties in laboratory (*in-vitro*) conditions. *Raphanus sativus* (Radish) and *Lactuca sativa* (Lettuce) as model receiver plants, *Chenopodium album* (common lambs' quarter), and *Amaranthus viridis* (pigweed) as test receiver weeds were used for the screening test.

In the short-term co-cultivation of wheat varieties with test species and weeds, the highest level of inhibition caused by the BARI Gom 21 variety resulted in 81% root growth inhibition of *Chenopodium album*. On the other hand, the case of shoot of *C. album* BARI Gom 27 showed maximum inhibition (49%). BARI Gom 21 (52%) resulted in the highest inhibitory effect on *R. sativus* root but the shoot growth was restricted by BARI Gom 25 (67%). While BARI Gom 30 (-48% inhibition in root) gave the stimulating effect on *R. sativus*. BARI Gom 30 (46%) and BARI Gom 21 (42%) showed over 40% growth inhibition on *A. viridis* root. The highest level of shoot inhibition in *A. viridis* was caused by BARI Gom 25

(53%). BARI Gom 26 (65%) and BARI Gom 21 (57%) demonstrated the highest growth inhibition of *L. sativa* roots. Interestingly, some varieties like BARI Gom 29 (-4% inhibition), BARI Gom 31 (-10% inhibition) stimulated the root growth of *L. sativa*. The highest (24%) shoot inhibition of *L. sativa* was observed from BARI Gom 28.

BARI Gom 21 caused the reduction of speed of germination (5.35, 4, 4.32, 5.83) against *R. sativus, L. sativa*, *C. album* and *A. viridis*. BARI Gom 21 also reduced coefficient of velocity of germination of *A. viridis* (1.92).

BARI Gom 21 reduced the weed density (14.66 m^{-2}, 28.33 m^{-2}, 33.33 m^{-2}) at 15, 25, and 35 DAS. BARI Gom 21 thus reduced weed biomass (12.02g m^{-2}) showing the highest weed control efficiency (86%) in the field test followed by BARI Gom 23 (84), BARI Gom 29 (81), BARI Gom 28 (41). There found different weed species viz., *Cynodon dactylon*, *Eleusine indica*, *Echinochloa colona*, *Cyperus rotundus, C. album*, *A. viridis*, *A. spinosus, Heliotropium indicum, Alternanthera philoxeroides*, *Corchorus acutangulus, Vicia sativa, Solanum caroliensis, S. torvum, Lindernia procumbens,* etc. on infested experimental plots Interestingly some major weed species of wheat including *C. album and A. viridis* found absent in BARI Gom 21 and BARI Gom 30 raised plots. Relative weed density and growth stage of different weed species of different wheat plots was also recorded.

After 50% flowering of wheat plants, an abundance of targeted weed species was measured by counting against each variety. Data of each species of weeds were recorded based on their stage of development viz., juvenile, vegetative, flowering, and mature stage. It was recorded that a major portion of the weeds was found in their vegetative stage. Several weeds were at the stage of flowering and mature stage at 50% flowering of wheat plants.

Simpson diversity index (SDI) was calculated maximum in BARI Gom 21 (0.82) and minimum in BARI Gom 22 (0.68). The SDI was correlated with the inhibition percentage of laboratory bioassay which results in a positive relationship (R^2 = 0.386).

In the growth parameter of wheat, although BARI Gom 21 showed the lowest (69.63 cm) plant height at harvest, tiller number hill^{-1} (4.03, 5.33, 6.33) at 30 DAS, 60 DAS, and at harvest, and effective tiller number per hill (5.67) was recorded the highest in BARI Gom 21 which suppressed weed. BARI Gom 21 (10.39g) also produced a higher thousand-grain weight.

Therefore, from the above discussion of the present research, the following findings are highlighted as the conclusions.

- The root and shoot growth of *Chenopodium album*, *Amaranthus viridis*, *Raphanus sativus,* and *Lactuca sativa* are inhibited by the biological activity of BARI Gom 21.
- A positive correlation was found between the field performance of what variety BARI Gom 21 in terms of weed control with *in vitro* screening.
- The growth and yield performance of BARI Gom 21 in the weed-infested field were higher in many regards than there of other varieties.
- Therefore, BARI Gom 21 was screened out as the most allelopathic potential among all Bangladesh wheat varieties.

Apparently, this is a currently underexplored line of research. The most interesting finding of the present work is identifying Bangladesh wheat variety ‘BARI Gom 21’ as allelopathic. The *in vitro* bioassay results were also successfully verified by comparing with field performance in terms of weed control, and successfully distinguished allelopathic effects from competition in crop-weed interference. This elite allelopathic wheat genotype could be used by breeding efforts to improve weed suppression traits in commercial varieties. Therefore, this research will be very beneficial for the resource-poor farmers of Bangladesh as well as for the researchers who work for the development of environmentally friendly weed management options. Furthermore, it will offer a better understanding of the communication networks that are allelochemically interceded between different species. The desired expansion of allelopathic knowledge might be useful to improve wheat production systems. Consequently, improved agricultural productivity would boost food production and help to discourse the world's food demand. However, additional research is necessary to isolate and identify allelochemical(s) from the Bangladesh wheat variety 'BARI Gom 21' as bioherbicide by which significance in nature of allelochemicals could be found for attributing the constant need for new chemistries and new target sites. Moreover, this wheat variety could be developed by breeding and by adopting other agronomic practices for obtaining optimum yield performance and tolerance to weeds.

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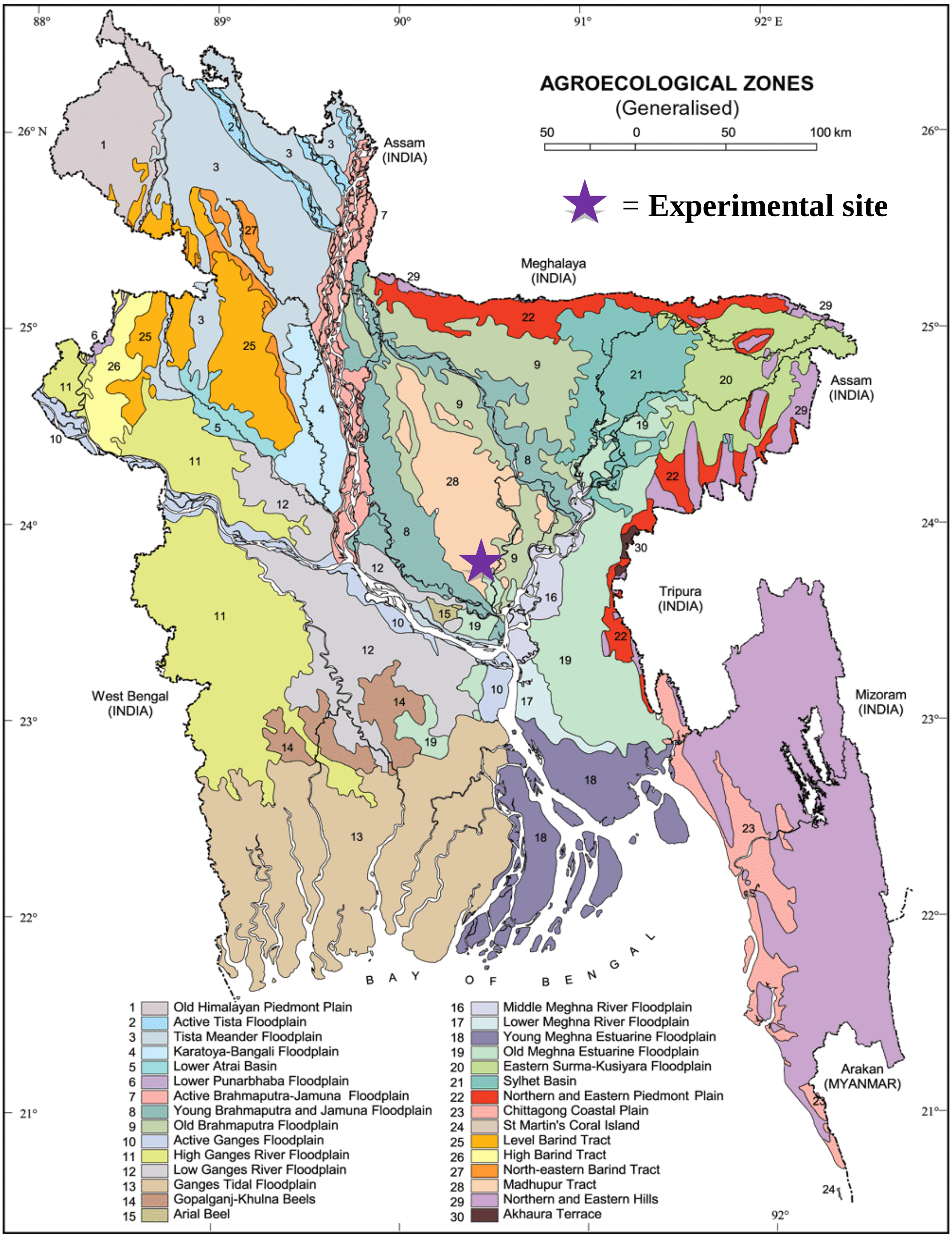
APPENDICES

Appendix I. Experimental location on the map of Agro-ecological Zones of Bangladesh



Appendix II. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Research Farm, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Deep Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0 - 15 cm depth)

Physical characteristics	
Constituents	**Percent**
Sand	26
Silt	45
Clay	29
Textural class	Silty clay
Chemical characteristics	
Soil characters	**Value**
pH	6.1
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total weeding (%)	0.03
Available P (ppm)	20.54
Exchangeable K (me/100 g soil)	0.10

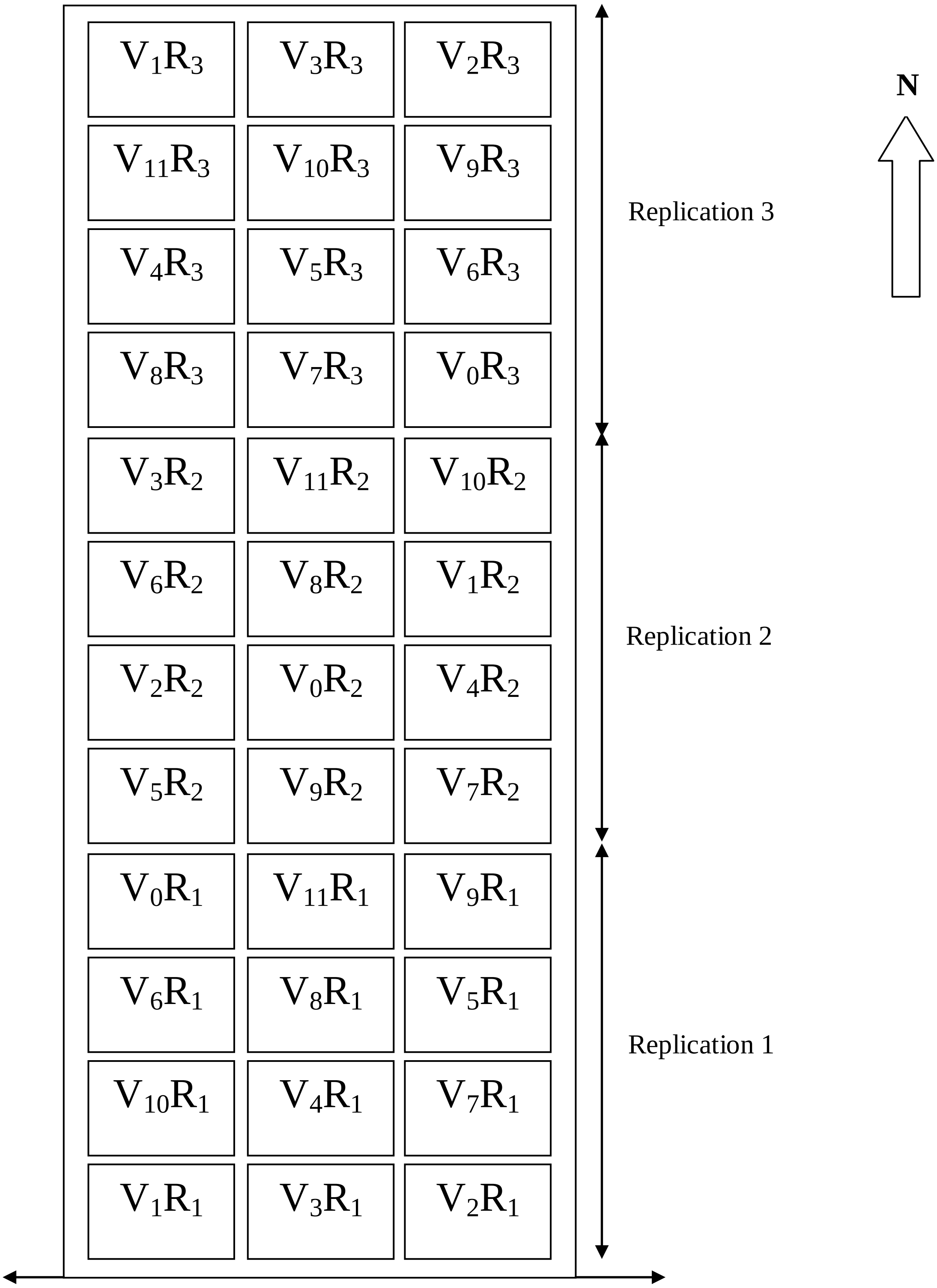
Appendix III. Monthly meteorological information during the period from November, 2018 to March, 2019

Year	Month	Air temperature (^0C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2018-2019	November	28.10	11.83	67.18	33
	December	25.00	9.46	60.53	0
	January	22.18	8.70	53.82	0
	February	23.10	10.83	45.18	19
	March	26.18	11.56	65.53	25

Source: Metrological Centre, Agargaon, Dhaka (Climate Division).

Appendix IV. Layout for experimental field

Total number of unit plots: 12 × 3 = 36
Unit plot size: 3 m × 2 m = 6 m^2
The main plot and unit plots were separated by 1m and 0.5m, respectively.



V_0= Weedy plot,V_1= BARI Gom 21, V_2= BARI Gom 22, V_3= BARI Gom 23, V_4= BARI Gom 24, V_5= BARI Gom 25, V_6= BARI Gom 28, V_7= BARI Gom 28, V_8= BARI Gom 30, V_9= BARI Gom 31, V_{10}= BARI Gom 31, V_{11}= BARI Gom 32.

Appendix V. Means square values for inhibition of *Chenopodium album* root in laboratory bioassay

Source of variation	df	Mean square value
Variety	12	989.72*
Error	39	14.65
CV (%)		8.42

* Significant at 5% level

Appendix VI. Means square values for inhibition of *Chenopodium album* shoot in laboratory bioassay

Source of variation	df	Mean square value
Variety	12	240.72*
Error	39	8.86
CV (%)		8.88

* Significant at 5% level

Appendix VII. Means square values for inhibition of *Amaranthus viridis* root in laboratory bioassay

Source of variation	df	Mean square value
Variety	12	1748.48*
Error	39	1.61
CV (%)		6.21

* Significant at 5% level

Appendix VIII. Means square values for inhibition (%) of *Amaranthus viridis* shoot in laboratory bioassay

Source of variation	df	Mean square value
Variety	12	824.65*
Error	39	4.21
CV (%)		6.16

* Significant at 5% level

^{NS} Not significant

Appendix IX. Means square values for inhibition of *Raphanus stivus* root in laboratory bioassay

Source of variation	df	Mean square value
Variety	12	3596.68*
Error	39	3.71
CV (%)		30.97

* Significant at 5% level

Appendix X. Means square values for inhibition of *Raphanus stivus* shoot in laboratory bioassay

Source of variation	df	Mean square value
Variety	12	263.50*
Error	39	8.11
CV (%)		5.36

* Significant at 5% level

Appendix XI. Means square values for inhibition of *Lactuca sativa* root in laboratory bioassay

Source of variation	df	Mean square value
Variety	12	2440.40*
Error	39	4.64
CV (%)		7.75

* Significant at 5% level

Appendix XII. Means square values for inhibition of *Lactuca sativa* shoot in laboratory bioassay

Source of variation	df	Mean square value
Variety	12	144.34*
Error	39	1.21
CV (%)		12.24

* Significant at 5% level

Appendix XIII. Means square values for germination inhibition of *Chenopodium album* in laboratory bioassay

Source of variation	df	Mean square value
Variety	12	15.06 ^{NS}
Error	39	16.02
CV (%)		4.06

^{NS} Not significant

Appendix XIV. Means square values for germination inhibition of *Amaranthus viridis* in laboratory bioassay

Source of variation	df	Mean square value
Variety	12	7.69 ^{NS}
Error	39	25.00
CV (%)		5.11

^{NS} Not significant

Appendix XV. Means square values for germination inhibition of *Raphanus sativus* in laboratory bioassay

Source of variation	df	Mean square value
Variety	12	20.19*
Error	39	21.15
CV (%)		4.70

* Significant at 5% level

Appendix XVI. Means square values for germination inhibition of *Lactuca sativa* in laboratory bioassay

Source of variation	df	Mean square value
Variety	12	10.90 ^{NS}
Error	39	15.38
CV (%)		3.97

^{NS} Not significant

Appendix XVII. Means square values for coefficient of germination of *Chenopodium album* in laboratory bioassay

Source of variation	df	Mean square value
Variety	12	0.103*
Error	39	0.00008
CV (%)		0.41

* Significant at 5% level

Appendix XVIII. Means square values for coefficient of germination of *Amaranthus viridis* in laboratory bioassay

Source of variation	df	Mean square value
Variety	12	0.288*
Error	39	0.0001
CV (%)		0.52

* Significant at 5% level

Appendix XIX. Means square values for coefficient of germination of *Raphanus sativus* in laboratory bioassay

Source of variation	df	Mean square value
Variety	12	0.081*
Error	39	0.0004
CV (%)		1.00

* Significant at 5% level

Appendix XX. Means square values for coefficient of germination of *Lactuca sativa* in laboratory bioassay

Source of variation	df	Mean square value
Variety	12	0.028*
Error	39	0.00009
CV (%)		0.46

* Significant at 5% level

Appendix XXI. Means square values for speed of germination of *Cenopodium album* in laboratory bioassay

Source of variation	df	Mean square value
Variety	12	4.84*
Error	39	0.015
CV (%)		1.83

* Significant at 5% level

Appendix XXII. Means square values for speed of germination of *Amaranthus viridis* in laboratory bioassay

Source of variation	df	Mean square value
Variety	12	1.07*
Error	39	0.001
CV (%)		0.71

* Significant at 5% level

Appendix XXIII. Means square values for speed of germination of *Raphanus sativus* in laboratory bioassay

Source of variation	df	Mean square value
Variety	12	2.24*
Error	39	0.004
CV (%)		1.17

* Significant at 5% level

Appendix XXIV. Means square values for speed of germination of *Lactuca sativa* in laboratory bioassay

Source of variation	df	Mean square value
Variety	12	1.28*
Error	39	0.002
CV (%)		0.91

* Significant at 5% level

Appendix XXV. Means square values for weed density in field experiment

Source of variation	df	Mean square value		
		15 DAS	25 DAS	35 DAS
Variety	11	159.82*	265.35*	680.63*
Replication	2	9.33	4.36	238.19
Error	22	21.97	17.36	44.07
CV (%)		19.26	11.94	13.16

* Significant at 5% level

Appendix XXVI. Means square values for Above-ground dry matter weight of weed plot^{-1}(g) in field experiment

Source of variation	df	Mean square value
Variety	11	1257.19*
Replication	2	8.17
Error	22	11.06
CV (%)		12.85

* Significant at 5% level

Appendix XXVII. Means square values for weed control efficiency in field experiment

Source of variation	df	Mean square value
Variety	11	109.94*
Replication	2	18.32
Error	20	12.10
CV (%)		4.50

* Significant at 5% level

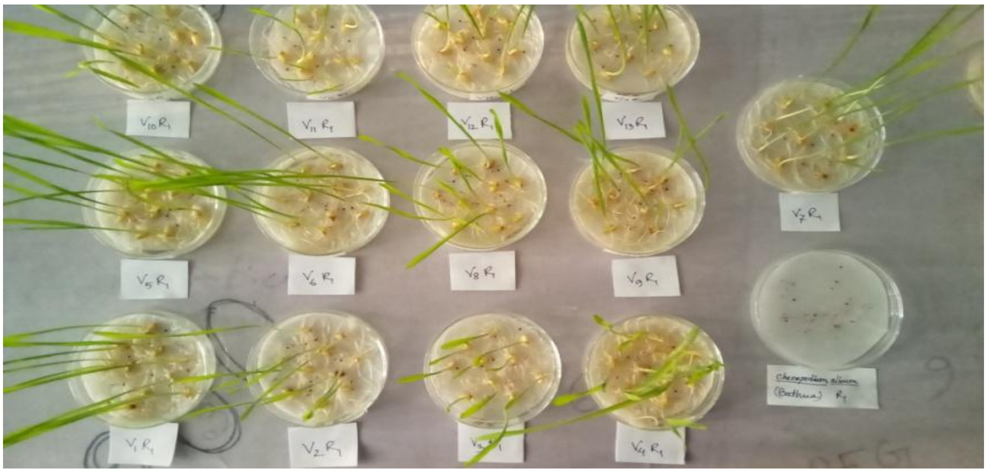


Plate 1. Placement of petri dish in laboratory for bioassay.

Plate 2. Root and shoot growth inhibited receiver plants in respect of control.

Plate 3. Field visit of SAURES authority during field experiment.

Plate 4. Weed grown in wheat plot.