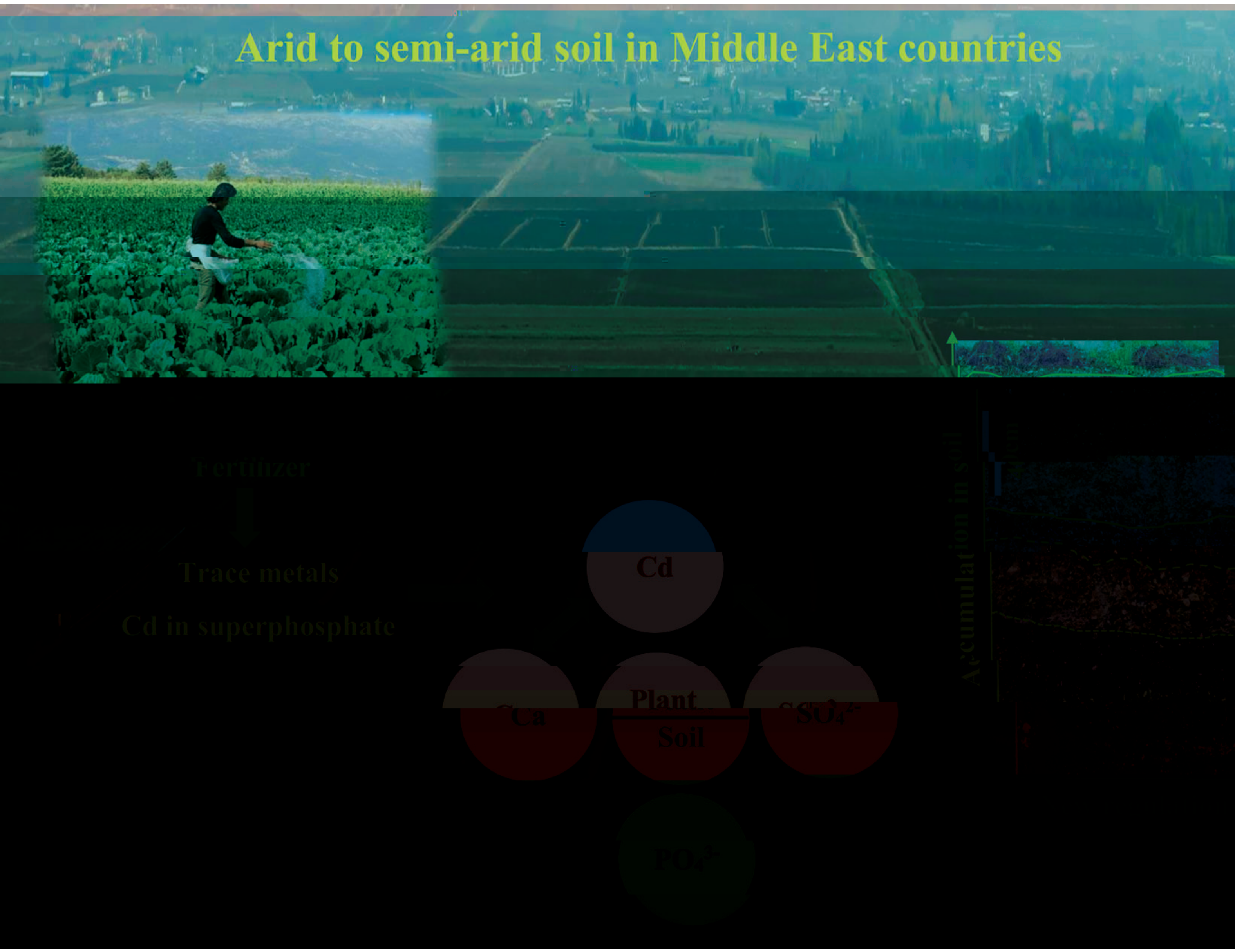
CSAWAC 45 (1) (2017) · Vol. 45 · No. 1 · January 2017

CLEAN
Soil Air Water

Renewables

Sustainability

Environmental Monitoring



01 | 2017

www.clean-journal.com

CLEAN Soil Air Water

Adnan Noor Shah [1]
Javaid Iqbal [2]
Shah Fahad [3]
Mohsin Tanveer [3]
Guozheng Yang [1]
Ejaz Ahmad Khan [4]
Babar Shahzad [5]
Muhammad Yousaf [6]
Waseem Hassan [6]
Abid Ullah [3]
Muhammad Adnan Bukhari [7]
Akram Salah [3]
Shah Saud [8]
Hesham Alharby [9]

[1]MOA Key Laboratory of Crop Ecophysiology and Farming System in the Middle Reaches of the Yangtze River, College of Plant Sciences and Technology, Huazhong Agricultural University, Wuhan, P. R. China
[2]Ghazi University, Dera Ghazi Khan, Punjab, Pakistan
[3]National Key Laboratory of Crop Genetic Improvement, MOA Key Laboratory of Crop Ecophysiology and Farming System in the Middle Reaches of the Yangtze River, College of Plant Sciences and Technology, Huazhong Agricultural University, Wuhan, P. R. China
[4]Gomal University, Dera Ismail Khan, KPK, Pakistan
[5]Department of Agronomy, University of Agriculture, Faisalabad, Pakistan
[6]College of Resources and Environment, Huazhong Agricultural University, Wuhan, P. R. China
[7]Department of Agronomy, University College of Agriculture and Environmental Sciences, The Islamia University of Bahawalpur, Bahawalpur, Pakistan
[8]Department of Horticulture, Northeast Agricultural University, Harbin, P. R. China
[9]Faculty of Science, Department of Biological Sciences, King Abdulaziz University, Jeddah, Saudi Arabia

Research Article

Allelopathic In uence of Sesame and Green Gram Intercrops on Cotton in a Replacement Series

Using a mixed culture replacement method, d ifferent plant species are planted with different densities per unit area. The bene ts of using this method are evident; however, phytotoxic/competitive effect s of these different plant species on each other are rarely studied, especially for cotton. Allelopathy is a biological phenomenon that can affect many aspects of plant ecology. A pot experiment was conducted to determine the individu al and/or interactive effects of cotton, sesame, and green gram on each other. Sesame, green gram, and cotton were sown in a replacement series in three different combinations: Sesame –cotton (3–0, 2–1, 1–2, 0–3); sesame–green gram (3–0, 2–1, 1–2, 0–3); and cotton –green gram (3–0, 2–1, 1–2, 0–3). The experiment was conducted using a completely randomized design with four replications; results revealed that inclusion of a legume crop (*i.e.*, green gram) signi cantly improved cotton shoot and root growth and yield, but sowing of sesame with cotton considerably decreased cotton plant perfo rmance as compared to gre5o

Correspondence: Prof. Guozheng Yang, MOA Key Laboratory of Crop Ecophysiology and Farming System in the Middle Reaches of the Yangtze River, College of Plant Sciences and Technology, Huazhong Agricultural University, 430070 Wuhan, P. R. China
E-mail: ygzh9999@mail.hzau.edu.cn

Abbreviations: EC, electrical conductivity; **GDP**, gross domestic product; **LSD**, least signi cant difference; **OM**, organic matter.

In Pakistan, agriculture is the single largest business sector, contributing 21% to the gross domestic product (GDP) and employing 44% of the workforce . However, growth performance of agriculture over the past 6 years has been volatile, ranging from 1.5 to 6.5%. Such uneven agricultural growth is mainly caused by the crop sector, which is associated with the vagaries of Mother Nature, pest attacks, adult erated pesticides, and others. Among other causes of low production, the cropping pattern, *i.e.*,

CLEAN Soil Air Water

wheat–rice or wheat–cotton, adopted every year is the major reason for decreased overall crop productivity. Pakistan is a subtropical country with sufficient irrigation and land resources and high-intensity sunlight for plant growth. Therefore, the possibility of raising two or more crops on the same piece of land during the year needs to be investigated for successful and efficient exploitation of these natural resources. Intercropping appears to be one way to proficiently utilize these natural resources. Currently, interest in intercropping is increasing among small growers because of their diversified needs and low income from the mono-cropping system. Therefore, with the prevalence of small holdings, surplus farms, family labor, overlapping growing seasons, low crop productivity, and subsistence farming, intercropping seems to be a promising strategy for increasing crop productivity, particularly in Pakistan.

Productivity of crop mixtures or intercropping systems may be increased or decreased depending on the inhibitory or stimulatory effects of the crops on each other, provided that growth resources (light, water nutrients, and space) are not limiting. Chemicals secreted by roots into the soil are broadly referred to as root exudates. Through the exudation of a wide variety of compounds, roots may regulate the soil microbial community in their immediate vicinity, maintain crop survival despite herbivores, encourage beneficial symbiosis, change the chemical and physical properties of the soil, and inhibit the growth of competing plant species [1]. Roots have the remarkable ability to secrete both low- and high-molecular-weight molecules in response to biotic and abiotic stresses. Synthesis and exudation of allelochemicals are typically enhanced by stress conditions like extreme temperatures, drought, and UV light exposure [2, 3]. Shah [4] and Shahid and Saeed [5] reported the effects of cotton with positive "A" values when grown in association with mung bean, soybean, mash bean, and linseed crops. Liu [6] also observed the autotoxic and phytotoxic effects of cotton on other crops involved in a long-term, continuous cropping system. Aqueous extracts of cotton significantly inhibited seed germination and seedling growth of wheat (*Triticum aestivum* L.), tomato (*Lycopersicon esculentum* L.), rape (*Brassica napus* L.), and alfalfa (*Medicago sativa* L.). Cotton was grown in soil continuously used for cotton cropping for 5–10 years. The adverse effects of allelochemicals were observed in monocultures and multiple cropping systems. Continuous monocultures cause the accumulation of phytotoxins and harmful microbes in soil, which give rise to phytotoxicity and soil sickness [7]. Crop rotation is practiced to eliminate the effects of monocultures, but the succeeding crop may be influenced by the phytotoxins released by the preceding crop. It was found that plant heights and fresh and dry weights of rice, sorghum, and sesame grown on the treated soil were lower than those of the controls, whereas plant heights and fresh and dry weights of maize, soybean, mung beans, and ground nuts were not affected. Duary [8] reported the effects of sesame (*Sesamum indicum*) leaf extract in different concentrations on germination, seedling growth, and dry matter production of black gram (*Vigna mungo*) and rice (*Oryza sativa*). Azizi et al. [9] studied the allelopathic effects of fenugreek extract on different field crops. When mung bean is grown in association with sesame, the nitrogen created by the mung bean seed is often beneficial for the sesame [10]. Metwally et al. [11] concluded that intercropping of corn with cotton had no adverse effect on the yield of crops and increased the seed yield. Therefore, cotton-based intercropping seems to be a promising strategy.

Efforts have been made to utilize the phenomenon of allelopathy for crop production. The results clearly demonstrate that the findings of allelopathic control of weeds, elimination of deleterious allelopathic effects of crops on other crops, or beneficial interactions in rotation or mixed cropping systems have direct bearings on crop production. The choice of crops grown in an intercropping system plays a vital role in productivity. Allelopathically active crops can be utilized in different ways in intercropping systems because of their high potential as possible bioherbicides [12], thus, contributing to sustainable agriculture. The target neighbor method, in which differing densities of a neighbor species are planted around a target plant, has been used to study phytotoxic effects [13]. Different studies have been conducted regarding the interactive effects of different crops, but there is very limited research on using different crops for their allopathic effects. Therefore, the present study was conducted to explore the allelopathic interaction of crops and to investigate suitable companion crops for intercropping systems.

2 Materials and methods

A pot experiment was conducted at College of Agriculture, Dera Ghazi Khan, Pakistan, during the summer of 2009; large pots (34 cm wide and 24 cm in depth; soil capacity of 25 kg) were used in the experiment. Sesame (*S. indicum*; T.S.3), green gram (*V. radiate*; hybrid mung), and cotton (*G. hirsutum*; C.M.496) were sown in different densities in a replacement series during summer (May 2009). Seeds were obtained from Punjab Seed Corporation of Pakistan. The experiment had a completely randomized design with four replications. Soil samples were collected from experimental areas of the college and were analyzed for physio-chemical properties: pH, 6.5; EC, 3.20 dS/m; OM, 0.70%; total N, 0.025%; available P, 6.50 mg/kg; available K, 116 mg/kg; and textural class silt clay. The N, P, and K fertilizers (urea, single super phosphate, and sulfate of potash, respectively) were applied at a rate of 6, 6, and 4 g per plot. Irrigation was managed throughout the growth of the plants. The cotton crop was protected against insects with imidacloprid 20% soluble concentrate (250 mL/100 L water) and deltamethrin 2.8% emulsifiable concentrate (300 mL/100 L water; Bayer Crop Sciences).

2.1 Treatment and measurements

There were three different planting densities for green gram and sesame intercropped with cotton: Sesame–cotton (3–0, 2–1, 1–2, 0–3), sesame–green gram (3–0, 2–1, 1–2, 0–3), and cotton–green gram (3–0, 2–1, 1–2, 0–3). Sesame, green gram, and cotton plants alone were maintained as controls.

The following measurements of sesame, cotton, and green gram were recorded during the course of the study: Shoot length, shoot dry weight, root length, root dry weight, and leaf area. For cotton, the number of sympodial branches per plant, number of bolls per plant, boll weight, 100-seed weight, seed cotton yield per plant, and ginning out-turn percentage (GOT%) were measured. For sesame, the number of capsules per plant, number of seeds per capsule, 1000-seed weight, and seed yield per plant were measured. For green gram, the number of branches per plant, number of pods per plant, number of seeds per pod, 1000-seed weight, grain yield per plant, and number of nodules per plant were measured.

2.2 Ginning out-turn percentage

Total yield of seed cotton was recorded and ginned with a single-roller electrical ginner. The lint obtained from the sample was weighed and GOT% was calculated with the following equation:

$$\mathrm{GOT}(\%) = \text{Weight of cotton lint} / \text{Weight of seed cotton} \times 100. \quad (1)$$

2.3 Data analysis

Data recorded during the course of the study were analyzed statistically by using MSTATC (a statistical micro-software program). Treatment means were separated by applying the least significant difference test at 5% probability levels [14].

3 Results and discussion

3.1 Effect of green gram and sesame on cotton shoot and root growth

The data demonstrated that sesame and green gram significantly ($p < 0.05$) affected cotton shoot length (cm) sown at varying densities in the replacement series. Initially, the trend of an increase in cotton shoot length was less for the treatment involving two cotton plants with one sesame plant followed by three sole cotton plants. Final shoot length of cotton was significantly affected by sesame and green gram planted at different densities in the replacement series (Tab. 1). This might be due to the different responses of the competing plant species. These results are in line with the findings reported by Velayutham et al. [15]. Final root length (cm) of cotton was significantly affected by sesame and green gram planted in the replacement series (Tab. 1). Comparatively longer roots were recorded (27.39 cm) when one cotton plant with two sesame or green gram plants per pot were sown, whereas shorter roots were observed for sole cotton plants (18.94 cm). The results were in contrast with those of Gill and Sandhu [16], who reported an inhibition in root growth when different crop species (*i.e.*, sunflower, maize, cotton, soybean, and pigeon pea) were intercropped. Furthermore, an increase in sesame plant density significantly reduced the dry weight of cotton shoots as compared to sole cotton plants. In contrast, the lowest biomass was obtained (291.27 g) from one cotton plant sown with two sesame plants. Green gram promoted the dry weight (297.68 g) of cotton shoots as compared to sole cotton (cotton plant alone with no intercrops). These results are in contrast to the findings of Azizi et al. [9], who found that sesame did not affect the fresh and dry weights of maize, mung bean, and groundnut when intercropped. Sowing of cotton mixed with sesame and green gram significantly affected the dry weight (g) of cotton roots (Tab. 1). As the number of sesame plants increased, the dry weight of cotton roots decreased compared to that of sole cotton, whereas intercropping of green gram with cotton significantly increased the dry weight (10.22 g) of cotton roots as compared to sesame. The inhibitory effect might be due to the higher competitive ability or allelopathic potential of sesame plants. However, an increase in the dry weight of cotton shoots with green gram might be due to the short stature of green gram plants or leguminous nature of the plant. These results are in contrast to the findings of Azizi et al. [9], who documented that sesame did not affect fresh and dry weights of maize, mung bean, and groundnut when intercropped.

3.2 Effect of green gram and cotton on sesame shoot and root growth

Cotton and green gram significantly influenced the final shoot and root length (cm) of sesame when intercropped at varying densities in a replacement series (Tab. 2). Cotton inhibited the root length of sesame as the number of cotton plants per pot increased, whereas longer roots were recorded (36.97 cm) when sole sesame plants were sown in pots. Comparatively, green gram increased the sesame root length (52.48 cm) as compared to cotton when intercropped with sesame. Dry weight (g) of sesame shoots was signicantly affected by sowing with cotton and green gram (Tab. 2). Higher shoot weight was observed (172.78 g) with sole sesame plants and lighter shoots were observed (133.87 g) with a sesame-cotton combination involving one sesame plant and two cotton plants. In contrast, green gram enhanced the dry biomass (236.52 g) of sesame shoots compared to sole sesame cropping. Bhatti et al. [17] also reported an increase in the biomass of sesame when intercropped with different legume crops. Compared to sole sesame cropping, cotton inhibited the dry weight of sesame roots as the number of cotton plants was increased. Heavier roots were recorded (10.68 g) when sole sesame plants were sown in pots and lighter roots were observed (6.93 g) when one sesame plant was sown with two cotton plants. However, green gram promoted the dry biomass of sesame roots. Bhatti et al. [17] also noticed a biomass increase in sesame grown with mixtures of different legume crops.

Table 1. Effect of sesame and green gram on growth of cotton shoots and roots

	Final shoot length (cm)	Final root length (cm)	Shoot dry weight (g)	Root dry weight (g)

3.3 Effect of cotton and sesame on green gram shoot and root growth

Green gram shoot and root growth was significantly influenced by cotton and sesame in a replacement series (Tab. 3). A considerable reduction in the dry weight of green gram shoots and roots was recorded as the numbers of cotton and sesame intercrop plants were increased with green gram. Maximum dry weight of green gram shoot and roots was observed (152.27 g) during sole cropping. However, the minimum weight of green gram roots was recorded when two plants, either cotton or sesame, were sown as intercrops with a single green gram plant. Cotton and sesame markedly affected the final shoot and root length (cm) of green gram when grown in a mixture (Tab. 3). Both cotton and sesame reduced the final shoot and root length of green gram as the numbers of these plants (cotton or sesame) were increased with a decrease in green gram plants. Morris and Garrity [18] also reported contradictory results indicating that sesame shoot length is increased during intercropping as compared to sole cropping. Longer green gram roots were observed (30.46 cm) during sole cropping. Shorter green gram roots were recorded (17.62 cm) when two cotton and two sesame plants were sown with a single green gram plant.

3.4 Effect of sesame and green gram on cotton yield and yield-related traits

Intercropping of sesame and green gram with cotton significantly affected the cotton sympodial branches per plant (Tab. 4). The number of sympodial branches decreased with the increase of sesame plants per pot. Fewer branches (14) were observed when only cotton was sown in pots and more branches (19) were recorded with one cotton plant was sown with two sesame plants. However, green gram promoted sympodial branches (20) as compared with sole cropping of cotton. The promotive effect of green gram might be due to the short stature of green gram plants or leguminous nature of the plant. Saeed et al. [19] reported results similar to these findings. Khan et al. [20] reported that during his experiment, all intercropping systems except cotton–mung bean, cotton–mash bean, and cotton–cowpea decreased the fruit-bearing branches; in this respect, these three were statistically on par with cotton grown alone.

Sesame and green gram significantly affected cotton boll weight (g) when grown in mixtures (Tab. 4). The heaviest bolls were recorded (2 g) when sole cotton plants were sown in pots; lighter bolls were observed (2.21 g) with one cotton plant sown with two sesame plants. However, improvement in boll weight was observed with the mixing of green gram (2.27 g) with cotton as compared to sole cotton. The inhibition in boll weight by sesame might be attributed to either competitive ability or allelopathic potential of sesame plants. The increase in boll weight of cotton with green gram might be due to the short stature of green gram plants. Goma and Radwan [21] also reported a reduction in boll weight when cotton was intercropped with different non-legumes. According to Khan et al. [20], cotton–mash bean, cotton–sesame, cotton–sesame, cotton–maize, and cotton–sorghum did not affect boll weight statistically, but in other intercropping systems it differed significantly. The number of bolls per plant was significantly affected by sesame and green gram

Sesame seed yield was significantly affected by cotton and green gram sown in a mixture (Tab. 5). Cotton suppressed seed yield with an increase in the number of cotton plants compared to sesame sole

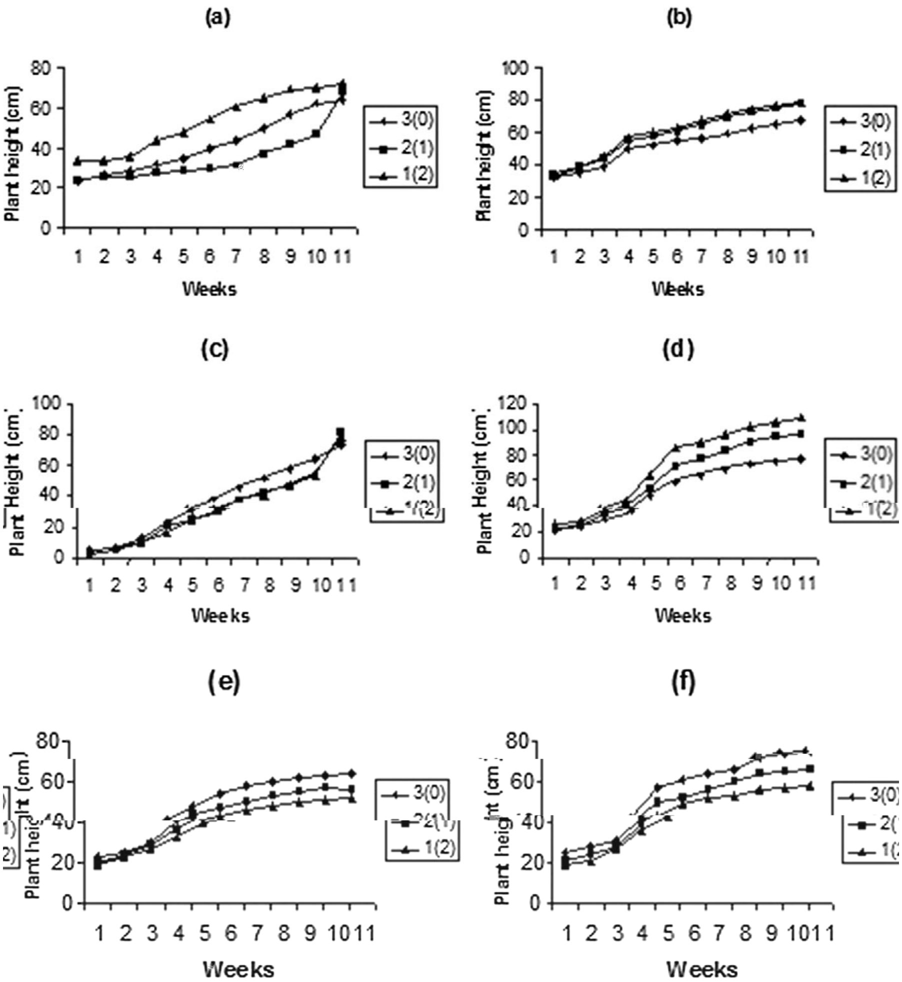


Figure 1. Effect of sesame (a) and green gram (b) on increasing rate of cotton height: 3 (0), three cotton plants per pot; 2 (1), two cotton plants with either one sesame (a) or one green gram (b) plant; 1 (2), one cotton plant with either two sesame (a) or two green gram (b) plants. Effect of cotton (c) and green gram (d) on increasing rate of sesame height: 3 (0), three sesame plants per pot; 2 (1), two sesame plants with either one cotton (c) or one green gram (d) plant; 1 (2), one sesame plant with either two cotton (c) or two green gram (d) plants. Effects of cotton (e) and sesame (f) on increasing rate of green gram height: 3 (0), three green gram plants per pot; 2 (1), two green gram plants with either one cotton (e) or one sesame (f) plant; 1 (2), 1 green gram plant with either two cotton (e) or two sesame (f) plants.

increased as the number of cotton and green gram plants increased; however, sesame density was decreased.

Sesame plant height (cm) was signi cantly affected by cotton and green gram planted at different densities in the replacement series (Fig. 1c and d). The tallest plants were recorded (61.26 cm) when two sesame plants were sown with one cotton plant in a sesame–cotton mixture. Green gram plant height (cm) was signi cantly affected by cotton. Initially, the increase in shoot length was even for all treatments; however, after the fth week, a gradual increase was noted. However, at the end of the experiment, the tallest plants were recorded (109.5 cm) when one sesame plant was sown with two green gram plants in the same pot. Short-stature plants were recorded (74.12 cm) when three sesame plants were sown per pot. An increase in shoot length with sesame mixed cropping in a replacement series (Fig. 1e and f) was reported by Velayutham et al. [15]. The combination of cotton and sesame inhibited the increase in plant height as compared to sole cropping. The tallest green gram plants were observed (75 cm) with sole cropping. The smallest green gram plants were recorded (52.38 cm) when two cotton plants and sesame plants were sown with a single green gram plant. Similarly, Khan and Khaliq [25] also reported an increase in plant height in intercropping systems. Plant height of mung bean intercropped with any of the planting patterns was statistically on par with the height of mung bean plants grown as a sole crop [25].

3.8 Allopathic effect of different combinations of plants on leaf area

The gradual increase in the leaf area of cotton was signi cantly affected by sesame and green gram in a mixed cropping system (Fig. 2a and b). The leaf area of cotton was adversely affected by sesame compared to green gram. More leaf area was recorded with sole cotton planting as compared to sesame in a cotton–sesame mixed cropping system. The increase in the leaf area of cotton with cotton–green gram cropping was almost constant. However, the difference was higher using the cotton–sesame mixed cropping system. An increase in productivity with intercropping compared to sole cropping has been attributed to better use of solar radiation and water [28]. Similar results were reported by Aduramigba et al. [30], who performed groundnut–cassava intercropping. The gradual

CLEAN Soil Air Water

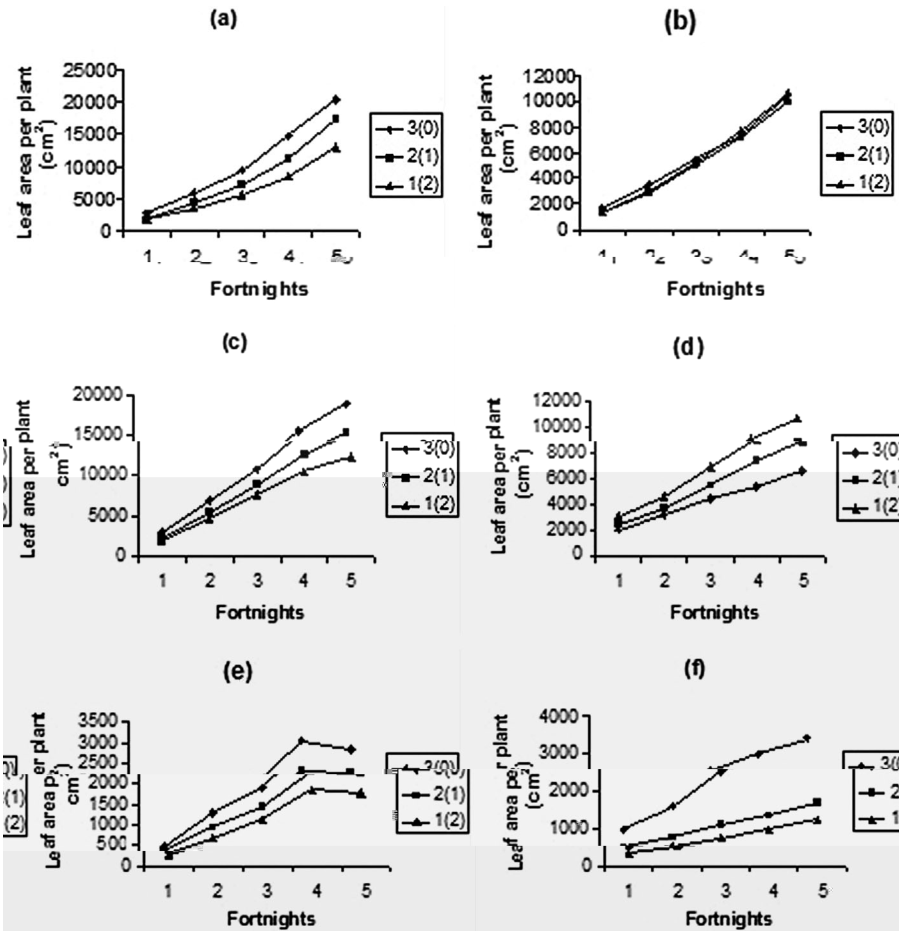


Figure 2. Effects of sesame (a) and green gram (b) on cotton leaf area: 3 (0), three cotton plants per pot; 2 (1), two cotton plants with either one sesame (a) or one green gram (b) plant; 1 (2), one cotton plant with either two sesame (a) or two green gram (b) plants. Effect of cotton (c) and green gram (d) on increasing rate of sesame height: 3 (0), three sesame plants per pot; 2 (1), two sesame plants with either one cotton (c) or one green gram (d) plant; 1 (2), one sesame plant with either two cotton (c) or two green gram (d) plants. Effects of cotton (e) and sesame (f) on increasing rate of green gram height: 3 (0), three green gram plants per pot; 2 (1), two green gram plants with either one cotton (e) or one sesame (f) plant; 1 (2), 1 green gram plant with either two cotton (e) or two sesame (f) plants.

increase in the leaf area of sesame was affected signi cantly by cotton and green gram in a mixed cropping system (Fig. 2e and f). The leaf area of sesame was adversely affected by cotton as compared to green gram. More leaf area was recorded with sole sesame planting as compared to cotton in a sesame –cotton mixed cropping system. However, more leaf area was recorded with one sesame plant and two green gram plants in the same pot. The gradual increase in leaf area of green gram was signi cantly affected by cotton and sesame grown in a mixed cropping system (Fig. 2c and d). Leaf area of green gram was adversely affected by both cotton and sesame as compared to sole cropping. However, the effect of sesame was more adverse as compared to cotton. Less leaf area was recorded when one green gram plant was mixed with either two cotton plants or two sesame plants in the same pot.

3.9 Allopathic effect of different combinations of plants on leaf number

With mixed cropping in a replacement series, the increase in the leaf count of cotton was signi cantly affected by sesame and green gram (Fig. 3a and b). During earlier stages, the increase in leaf count was not affected; less competition of plants during initial stages may be the main reason for this. Sesame was more suppressive than green gram. The maximum number of leaves was recorded with sole cotton as compared to a cotton –sesame mixed cropping system. The most leaves were observed in one cotton plant with two green gram plants in a cotton –green gram mixed cropping system. These results are in accordance with the ndings of Keating and Carberry [31], who reported that intercropping makes ef cient use of available nutrients. Morris and Garrity [18] also reported an increase in the number leaves per plant in an intercropping system. Usmanikhail et al. [32] observed maximum leaf length, leaf area, and leaves per plant in sugar beet when intercropped with cereal and lentil; however, the results of this experiment were contradictory to the current results.

Cotton and green gram signi cantly affected the increase in leaf count of sesame when cotton and green gram were grown in mixture (Fig. 3c and d). Initially, the increase in leaf count was not affected. This might be because there is less competition between the plants during the initial stages. The increase in leaf count for

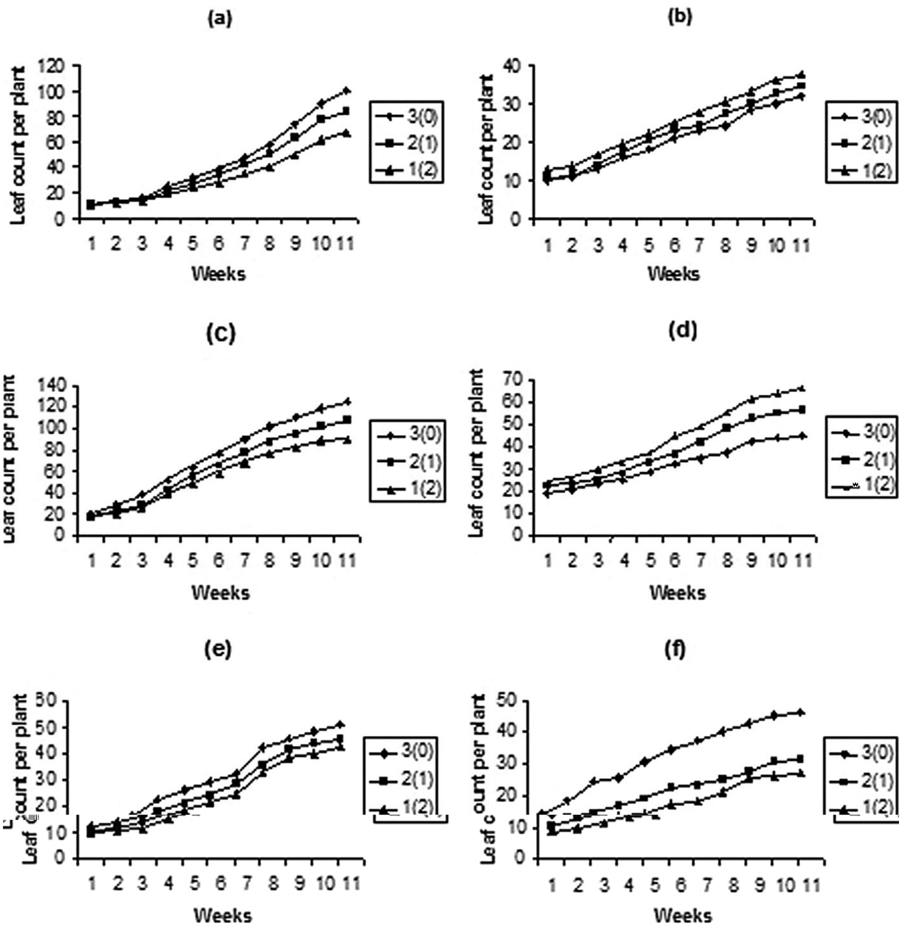


Figure 3. Effects of sesame (a) and green gram (b) on cotton leaf count: 3 (0), three cotton plants per pot; 2 (1), two cotton plants with either one sesame (a) or one green gram (b) plant; 1 (2), one cotton plant with either two sesame (a) or two green gram (b) plants. Effect of cotton (c) and green gram (d) on increasing rate of sesame height: 3 (0), three sesame plants per pot; 2 (1), two sesame plants with either one cotton (c) or one green gram (d) plant; 1 (2), one sesame plant with either two cotton (c) or two green gram (d) plants. Effects of cotton (e) and sesame (f) on increasing rate of green gram height: 3 (0), three green gram plants per pot; 2 (1), two green gram plants with either one cotton (e) or one sesame (f) plant; 1 (2), 1 green gram plant with either two cotton (e) or two sesame (f) plants.

sesame was suppressive when it was planted with cotton as compared to green gram. More leaves were recorded for sole sesame in a sesame–cotton mixed cropping system. However, more leaves were observed in one sesame plant with two green gram plants per pot in a sesame–green gram mixture. Cotton and sesame signi cantly affected the increase in leaf count for green gram (Fig. 3e and f). Initially, the increase in leaf count was not affected. This might be because there is less competition among plants during the initial stages. The increase in leaf count for green gram was less suppressive when it was planted with cotton as compared to sesame. More leaves were recorded for sole green gram cropping in a cotton – green gram and sesame–green gram mixed cropping system. Leaf count was adversely affected when one green gram plant and two sesame or two cotton plants were sown in the same pot. Saleem [33] also reported that the plant population (m ^{2}) of lentil was reduced signi cantly by a wheat crop as compared to sole planting.

3.10 Concluding remarks

This report provides an understanding of yield performance and other agronomic attributes in response to the intercropping in uences of sesame, green gram, and cotton in a replacement series studies. Our study revealed that cotton and sesame both reduced the growth and yield of green gram; however, when green gram is planted with cotton and sesame, its growth is promoted. However, the response of cotton to sesame and the response of their inverse combinations show different effects regarding the growth and yield of these crops. Our data indicate that high-stature crops can be grown with short-stature leguminous crops as companion crops.

Acknowledgment

We are grateful for the support from the National Natural Science Foundation of China (31271665).

The authors have declared no con ict of interest.

References

[1] T. S. Walker, H. P. Bais, E. Grotewold, J. M. Vivanco, Root Exudation and Rhizosphere Biology, *Plant Physiol.* **2003**, *132*, 44–51.

[2] S. Fahad, S. Hussain, S. Saud, M. Tanveer, A. A. Bajwa, S. Hassan, A. N. Shah, et al. A Biochar Application Protects Rice Pollen From High-Temperature Stress, *Plant Physiol. Biochem*. **2015**, *96*, 281–287.

[3] S. Fahad, S. Hussain, S. Saud, F. Khan, S. Hassan, M. Amanullah, F. Arif, et al. Exogenously Applied Plant Growth Regulators Affect Heat-Stressed Rice Pollens, *J. Agron. Crop Sci*. **2016**, *202*, 139–150.

[4] K. H. Shah, S. H. Siddiqui, M. Y. Memon, M. Imtiaz, M. Aslam, Effect of Different Nitrogen Management Practices and Planting Geometries in Cotton Mungbean Intercropping System, *Asian J. Plant Sci*. **2002**, *1* (*4*), 358–360.

[5] M. R. M. Shahid, M. Saeed, Competitive Relationship of Component Crops in Different Wheat-Based Intercropping Systems, *J. Anim. Plant Sci*. **1997**, *7*, 37–39.

[6] J. P. Liu, Allelopathic Effects of Cotton Plant Extracts on Different Crop Plants, *Weed Sci*. **2008**, *39*, 195–199.

[7] S. S. Narwal, *Allelopathy in Crop Production*, Scienti c Publishers, India **2005**. p. 171.

[8] B. Duary, Effect of Leaf Extract of Sesame (*Sesamum Indicum* L.) on Germination and Seedling Growth of Black Gram (*Vigna Mungo* L.) and Rice (*Oryza Sativa* L.), *Allelopathy J*. **2002**, *10*, 153–156.

[9] G. Azizi, M. Jahani Kondori, A. Siah-Marguee, L. Alimoradi, Bioassay Study of Fenugreek Extract's Allelopathic Effects on the Germination and Growth of Several Crops and Weeds, *J. Plant Breeding Crop Sci*. **2011**, *3* (*10*), 229–239.

[10] M. Saeed, S. A. Khan, M. B. Gill, R. Ahmad, Production Potential and Net Income of Different Wheat-Based Legume and Non-Legume Intercropping Systems, *Sci. Int*. **1997**, *9*, 55–61.

[11] A. E. A. A. Metwally, M. M. Shak, M. N. Sherief, T. I. Abdel-Wahab, Effect of Intercropping Corn on Egyptian Cotton Characters, *J. Cotton Sci*. **2012**, *16*, 210–219.

[12] H. P. Singh, D. R. Batish, R. K. Kohli, Allelopathic Interaction and Allelochemicals New Possibilities for Sustainable Weed Management, *Crit. Rev. Plant Sci*. **2003**, *22*, 239–311.

[13] J. D. Weidenhamer, Distinguishing Resource Competition and Chemical Interference Over-Coming the Methodological Impasse, *Agron. J*. **1996**, *88*, 866–875.

[14] R. G. D. Steel, J. H. Torrie, *Principles and Procedures of Statistics*, 2nd ed., McGraw Hill, New York **1984**.

[15] A. A. Velayutham, M. Ali, V. Veerabadran, S. Sanbagavalli, Bioefcacy of Herbicides and Their Application Techniques in Cotton Based Intercropping Systems, *Acta Agron. Hung*. **2001**, *49*, 261–271.

[16] D. S. Gill, K. S. Sandhu, Studies on Allelopathic Effect of Sun ower (*Helianthus Annuus*) Residues on Succeeding Kharif Crops, *Ind. J. Ecol*. **1993**, *20*, 169–172.

[17] I. H. Bhatti, R. Ahmad, A. Jabbar, M. S. Nazir, T. Mahmood, Competitive Behaviour of Component Crops in Different Sesame-Legume Intercropping Systems, *Int. J. Agric. Biol*. **2006**, *2*, 165–167.

[18] R. A. Morris, D. P. Garrity, Resource Capture and Utilization in Intercropping, *Field Crops Res*. **1993**, *34*, 303–317.

[19] M. R. Saeed, M. Shahid, A. Jabbar, E. Ullah, M. Bismillah, Agro-Economic Assessment of Different Cotton-Based Inter/Relay Cropping Systems in Two Geometrical Patterns, *Int. J. Agric. Biol*. **1999**, *4*, 234–237.

[20] M. B. Khan, M. Akhtar, A. Khaliq, Effect of Planting Patterns and Different Intercropping Systems on the Productivity of Cotton (*Gossypium Hirsutum* L.) Under Irrigated Conditions of Faisalabad, *Int. J. Agric. Biol*. **2001**, *3*, 432–435.

[21] M. A. Goma, Radwan, The Effect of Intercropped Cotton Present With Soyabean on Yield of Soyabean Plant, *Ann. Agr. Sci., Moshtohor J*. **1991**, *29*, 745–756.

[22] A. Malik, A. Quadri, M. M. Al Razaq, Studies on Effect of Intercropped Maize in Cotton Fields, *Assoc. J. Agric. Sci*. **1999**, *22*, 337–349.

[23] K. M. Clark, R. L. Myers, Intercrop Performance of Pearl Millet, Amaranth, Cowpea, Soybean and Guar in Response to Planting Pattern and Nitrogen Fertilization, *Agron. J*. **1994**, *86*, 1097–1102.

[24] J. Iqbal, Z. A. Cheema, M. An, Intercropping of Field Crops in Cotton for the Management of Purple Nutsedge (*Cyperus Rotundus* L.), *Plant Soil* **2007**, *300*, 163–171.

[25] M. B. Khan, A. Khaliq, Production of Soybean (*Glycine Max* L.) as Cotton Based Intercrop, *Res. Sci*. **2004**, *15*, 79–84.

[26] V. Subramanian, B. Maheswari, Physiological Responses of Groundnut to Water Stress, *Indian J. Plant Physiol*. **1992**, *33*, 130–135.

[27] A. Nishat, Studies on Agro-Economic Relationships of Component Crops in a Lentil-Wheat Intercropping System, *MSc Thesis*, University of Agriculture Faisalabad, Pakistan **1989**.

[28] R. W. Willey, Resource Use in Intercropping Systems, *Agric. Water Manage*. **1990**, *17*, 215–219.

[29] Y. R. Aladakatti, S. S. Hallikeri, R. A. Nandagavi, A. Y. Hugar, N. E. Naveen, Effect of Intercropping of Oilseed Crops on Growth, Yield and Economics of Cotton (*Gossypium hirsutum*) Under Rainfed Conditions, *Karnataka J. Agri. Sci*. **2011**, *24*, 280–282.