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Weed management using crop competition in Pakistan: A review

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ABSTRACT

Agriculture occupies an important place in improving the living standards of farmers in Pakistan. About 90% of farm earnings rely on the cultivation of sugar, fibre, cereals and legumes. Due to lack of essential resources and technical expertise, every year thousands of farmers fail to reach maximum yield potential. Over 70% of farmers own less than 5 ha in Pakistan; therefore, it is uneconomic to employ costly mechanical and chemical strategies for the control of pests in their crops. Among these pests, we eds are considered to be the major obstacle to crop production, and can ultimately result in crop failure. Traditionally, manipulation of cropping techniques was employed for the control of weeds; later on, development of synthetic chemical herbicides made it easier to control weeds in a very short time period. However, over time the increased use of herbicides has led to the development of herbicide resistant weeds. Furthermore, increasing environmental concerns, weed population shifts, and increased managerial costs have made it difficult for farmers to control these weed species within their limited economic resources. Nowadays, scientists and research organizations are being urged to provide innovative weed management solutions, with minimal ecological impacts. Studies have revealed the importance of cultural strategies for the management of weeds in different cropping systems. Research has proved that alternation of cultural practices, and selection of competitive crop cultivars, could be a possible strategy to minimize the competitiveness of weeds. Increased crop densities, narrower row spacing, intercropping and alternation in row directions are among the weed control strategies gaining rapid attention in many countries. Unfortunately, limited information is available about weed management using crop competition in Pakistan. This review article focusses on the importance of these agronomic practices in reducing the competitive potential of weeds, for their effective and appropriate management in major crops of Pakistan. It is intended to assist researchers in the design of economically viable and eco-friendly weed management strategies, which will aid in eliminating the burden of herbicides and mechanical cultivation from farmer's production costs.

1. Introduction

Agriculture contributes significantly to the economic growth of Pakistan through providing food, supplying raw material to industries, earning foreign exchange, and through employing a large portion of the population (Afzal and Ahmad, 2009). It adds about 20.9% to global domestic production (GDP), and 43.5% in employment, playing a significant role in the socio-economic development of the country (Anonymous, 2015). Cereals such as wheat (*Triticum aestivum* L.), rice (*Oryza sativa* L.), and maize (*Zea mays* L.) are the main food crops and major foundations for earning foreign exchange (Afzal and Ahmad, 2009). Pakistan is known for its "basmati rice" as a primary source of aromatic fine rice; the country's major agricultural export product (Akram, 2009). Moreover, Pakistan is the fifth largest producer and the third largest exporter of raw

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cotton (*Gossypium hirsutum* L.) in the world, providing a livelihood to more than 50 million people (Morris, 1989). Sugarcane (*Saccharum officinarum* L.) is widely cultivated in Sindh, Punjab, and Khyber Pakhtunkhwa provinces, and is thought to be the largest source of government revenue in the form of taxes and duties (Nazir et al., 2013). These major agronomic crops, including legumes, account for 5.3% of GDP. Therefore, realising maximum yield potential of these crops is important for the uninterrupted growth and development of the agriculture sector, as well as for the capacity utilization and growth of industries dependant on agriculture for raw materials (Nosheen and Iqbal, 2008).

In addition to other biotic and abiotic constraints, weeds exert a significant effect on the potential yield of major crops (Siddiqui et al., 2010; Tanveer et al., 2015). Weeds interfere with crops for nutrients, soil moisture, space, light, and CO_2, which leads to reduced crop yield and deterioration of product quality (Khan et al., 2013). 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; Ali et al., 2015a, b). The relationship between weed-crop competition duration, and competition pressure exerted on the crop, are considered to be the main reasons for reduced crop yield (Fahad et al., 2014). Weeds inflict about 20–30% of yield losses in different crops of Pakistan (Hussain et al., 2007). The average estimated weed-caused crop yield loss is 11.5% in Pakistan, compared with the global average of 9.5% (Rabbani et al., 2013). Weed infestation impacted ≈3.4 million tons of cereal production, with an enormous loss of US$ 1 billion per annum in Pakistan (Saeed et al., 2010a). Hussain et al. (2013) suggested that enhancement of crop yield in major crops through weed control is a key factor in improving food security in Pakistan.

In Pakistan, poor weed control approaches, or uninterrupted weed growth, results in severe annual yield losses in wheat (17–25%), rice (20–63%), sugarcane (10–35%), and cotton (13–31%) (Abbas, 2006). Quality and yield of these crops could be increased significantly through controlling weeds before the critical period, or through suppressing their competitive potential (Fahad et al., 2015; Hussain et al., 2015). Manual, mechanical, and chemical methods, or their integration, are commonly employed for the control of noxious and invasive weed species (Rabbani et al., 2013). However, increasing labour shortages, higher wages, prevailing weather conditions, unavailability of inputs, and the financial resources available to farmers are major hurdles for the effective and timely management of weeds using these approaches (Khaliq et al., 2011, 2013b). In addition to this, excessive and imprecise application of chemical herbicides, raise concerns relating to herbicide resistance in weeds, weed population shifts, and crop phytotoxicity with harmful consequences for ecological and human health (Marwat et al., 2011). With the transition to extensive use of herbicides, there has been a tendency to neglect other components of the agro-ecosystem that have an impact on weed: crop competition; in particular, modern crop cultivars, developed in weed-free situations, are less competitive to weeds as compared to older cultivars (Snaydon, 1984). Another concern is that, while herbicides may provide effective weed control, herbicide residuals can contaminate crop products and the soil, with harmful consequences for humans and the environment (Riaz et al., 2007). Herbicide residues in the soil can also negatively influence crop seed germination and seedling performance, with adverse effects on growth, yield, and product quality.

Several non-chemical approaches, such as the use of crop interference, crop rotation, hand weeding, and selective tillage operations, were widely employed for weed control many cropping systems before the introduction of herbicides (Parish, 1990; Regnier and Janke, 1990; Anderson, 2015). Cropping systems with intensive chemical usage, little biodiversity and increased environmental and economic costs have become increasingly apparent over the last two decades (Reganold et al., 1990; Conway and Barbier, 1990; Kuk et al., 2001). The promise of reduced environmental hazards, while maintaining economic crop production, has revived interest in achieving weed management through crop competition. This review presents research on weed management through increased crop interference, bearing in mind the costs and benefits achieved using conventional practices to manage weeds in major crops. We have highlighted research gaps in the cultural management of weeds in Pakistan, which will help researchers in identifying appropriate crop management strategies that exert a negative effect on the growth and development of weed species in the major crops. This article will help researchers and farmers to design more economic weed control strategies through altering the cultural operations in major agronomic crops.

2. Influence of weed-crop competition on crop yield

In an agro-ecosystem, weeds usually compete with crops for nutrients, moisture, space, light, and gaseous exchange, which ultimately reduces the crop quality and yield (Qasim and Foy, 2001). In addition to the physical competition, weeds exert a negative influence on crop production through releasing allelopathic chemicals, potentially resulting in complete crop failure (Gupta, 2004; Ali et al., 2013a).

2.1. Wheat

In Pakistan, wheat is cultivated on 9.18 million hectares, with an annual production of 24.47 million tons and an average yield of 2775 kg ha^{-1} (Anonymous, 2015). It is the leading food grain occupying 37% of the total cropped area. It contributes about 2.1% of national GDP, which is low compared with many wheat growing countries (Abbas et al., 2009). This lower level of wheat production can be attributed to high weed infestation, poor fertilizer management practices, and water scarcity (Jabran et al., 2011). Of these factors, weeds are considered to be the major yield limiting factor, causing massive yield losses of 18–30% in wheat production annually (Ashiq and Cheema, 2005).

In wheat growing areas of Pakistan, more than 45 weed species have been reported as frequently occurring in high densities, with approximately 28 species in Punjab (Anjum et al., 2007). Depending on weed density, grain yield losses range from 20 to 50% in wheat (Hussain et al., 2012). Similarly, Khan and Haq (2002) reported weeds as a major threat to wheat productivity, accounting for more than 48% potential yield loss under heavy weed infestation. In another study, crop vegetative growth and grain yield were reduced by up to 87 and 76%, respectively, as a consequence of increasing the duration of competition between two wheat cultivars (Inqalab-91 and Punjab-96) and several associated weed species (Siddiqui et al., 2010).

A significant reduction in wheat yield was recorded (28 and 34% in mid- and late-sown wheat crop, respectively) in the presence of *Phalaris minor* Retz. at 40 plants m^{-2} (Hussain et al., 2015). Increased yield losses (76%) were recorded in Inqalab-91 by *Poa annua* L., followed by *Coronopus didymus* L. (75%), with average yield losses of 60–70% caused by *Rumex dentatus* L., *Phalaris minor*, *Chenopodium album* L., and *Medicago denticulata* L. Similarly, more than 30% reduction in wheat yield, and with 1% reduction in protein content, was recorded when the crop was allowed to compete with *P. minor* at varying densities of 15, 16, and 17 plants m^{-2} (Khan et al., 2007). In the presence of *P. minor* and *Avena fatua* L, adverse effects on wheat yield and attributing components have also been

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