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Assessment of yield and economic losses in agriculture due to weeds in India

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ABSTRACT

Weeds are notorious yield reducers that are, in many situations, economically more harmful than insects, fungi or other crop pests. Assessment of crop yield and economic losses due to weeds in agriculture is an important aspect of study which helps in devising appropriate management strategies against weeds. A study was conducted to estimate the yield and economic losses due to weeds using the data from 1581 On-Farm Research trials conducted by All India Coordinated Research Project on Weed Management between 2003 and 14 in major field crops in different districts of 18 states of India. The study revealed that potential yield losses were high in case of soybean (50–76%) and groundnut (45–71%). Greater variability in potential yield losses were observed among the different locations (states) in case of direct-seeded rice (15–66%) and maize (18–65%). Three factors viz. location (state), crop, and soil type significantly ($p < .0001$) explained the variability in actual yield losses due to weeds at farmers' fields. Significant differences were also observed between different locations, crops and soil types. Actual economic losses were high in the case of rice (USD 4420 million) followed by wheat (USD 3376 million) and soybean (USD 1559 million). Thus, total actual economic loss of about USD 11 billion was estimated due to weeds alone in 10 major crops of India viz. groundnut (35.8%), soybean (31.4%), greengram (30.8%), pearlmillet (27.6%), maize (25.3%), sorghum (25.1%), sesame (23.7%), mustard (21.4%), direct-seeded rice (21.4%), wheat (18.6%) and transplanted rice (13.8%).

1. Introduction

Reduction in economic losses in agricultural production due to abiotic and biotic factors is of utmost importance in modern day input-intensive agricultural systems. Sustaining the production levels demands devising newer strategies for mitigating the ill-effects of these adverse factors. As with abiotic causes, especially the lack or excess of moisture in the growth season, extreme temperatures, high or low irradiance and nutrient supply, biotic stresses have the potential to reduce yields substantially (Oerke, 2006). Among the major biotic constraints, weeds are considered as the most harmful to agricultural production besides affecting agrobiodiversity and natural water bodies. They also affect the crop production indirectly, by competing with the crop for resources, sheltering crop pests, interfering with water management, reducing the yield and quality, and subsequently increasing the cost of processing (Zimdahl, 2013). Therefore, weed management is the major and important part of crop production.

In India, reduction in crop yield was estimated as 31.5% (22.7% in winter and 36.5% in summer and rainy seasons) by weeds (Bhan et al., 1999). Whereas, the economic losses due to weeds in India was estimated as INR 20 to 28 billion about two decades ago (Sahoo and Saraswat, 1988; Sachan, 1989). In another study, it was reported that loss in agricultural production due to weeds amounts to INR 1050 billion per annum (NRCWS, 2007; Varshney and PrasadBabu, 2008).

In general, the yield loss due to weeds is almost always caused by a group of different weed species, and these weeds may have substantively different competitive ability (Weaver and Ivany, 1998; Milberg and Hallgren, 2004). Practically, it is very difficult to estimate the yield loss due to single weed species and therefore, it is estimated as the collective efforts by all the weeds. Overall, weeds produced the highest potential loss (34%), with animal pests and pathogens being less important (losses of 18 and 16%) worldwide (Oerke, 2006).

As far as studies on yield loss at global level is concerned, Milberg and Hallgren (2004) explored the large-scale patterns in yield loss in cereals due to weeds in Sweden and mentioned that weed biomass explained 31% of the variation in yield loss due to weeds. Whereas, O'Donovan et al. (2005) developed various regression equations in western Canada to estimate the effects of weeds on yield loss of field crops. Oliveira et al. (2014) also presented that insect, pests cause an average annual production loss of 7.7% in Brazil, which is a reduction of approximately 25 million tonnes of food, fibre and biofuels. They also estimated the total annual economic losses as approximately USD

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17.7 billion. Soltani et al. (2016) also estimated average yield loss in corn as 50%, which equates to a loss of 148 million tonnes of corn valued at over USD 26.7 billion annually in the United States and Canada.

Most of the studies conducted in past are more or less based on the experimental data which may not be always representative for field situation. Although, estimation of yield losses from experimental situation is subject to local effects and sometimes it is valid only for some cropping situation, it may be difficult to extrapolate the results for farmers' yield losses (Milberg and Hallgren, 2004). The reason may be the experimental situations that might not be the representative for a field condition (Savary et al., 1998). Further, it is more realistic to establish results from field trials comparing the different treatments in the farmers' field (Walker, 1983; Zanin et al., 1992; Oerke et al., 1994; Oerke and Dehne, 1997; Tamado et al., 2002). Hence, to observe the magnitude and variability of yield losses due to pests, data from farmers' fields are needed (Friesen and Shebeski, 1960; Taylor and Lill, 1986). Therefore, the study has been taken to reassess the yield losses (potential and actual) estimates along with economic losses by weeds affecting major field crops grown in India based on data from farmers' fields.

2. Materials and methods

2.1. Field trials

The study was conducted to estimate the yield losses and economic losses due to weeds using the data from a total of 1581 on-farm research trials conducted by All India Coordinated Research Project on Weed Management (AICRP-WM) during 2003-14 in 10 major field crops in different regions of India (Fig. 1; Table 1). The study centres were located in Bihar, Chhattisgarh, Gujarat, Haryana, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan, Tamil Nadu, Telangana, Uttar Pradesh, Uttarakhand and West Bengal (Table 2). The information and data of on-farm research trials, conducted during 2003-14, were collected from different centres located in these states. These trials were conducted having plot size of about 1000 m^2 for each treatment. For the study, yield data of three treatment plots *viz.* farmers' practice (1 hand weeding/mechanical weeding), weedy check (no control of weeds) and weed free were used to calculate yield losses. Weed free situation was maintained with the use of herbicide supplemented by hand weeding. Yield data of farmers' practice was used to estimate actual yield losses in different crops whereas; yield data of weedy check plot was used to estimate the potential yield loss *vis a vis* weed free situation.

Table 1
Number of trials considered for the calculation of yield losses due to weeds across the India.

Season	Crop	Number of trials
Rainy	Transplanted rice (*Oryza sativa* L.)	461
	Direct-seeded rice (*Oryza sativa* L.)	195
	Pearl millet (*Pennisetum glaucum* (L.) R. Br.)	72
	Soybean (*Glycine max* (L.) Merr.)	132
	Sorghum (*Sorghum bicolor* (L.) Moench)	39
	Groundnut (*Arachis hypogaea* L.)	24
	Greengram (*Vigna radiata* (L.) R. Wilczek)	10
	Sesame (*Sesamum indicum* L.)	19
Winter	Wheat (*Triticum aestivum* L.)	490
	Maize (*Zea mays* L.)	98
	Mustard (*Brassica* spp.)	41

2.2. Calculation of yield losses due to weeds

Actual and potential yield losses were calculated using following formulas as given in Milberg and Hallgren (2004); Galon and Agostinetto (2009); Soltani et al. (2016):

$$\text{Actual yield loss due to weeds} = \left(\frac{WF_y - FP_y}{WF_y}\right) \times 100 \quad (1)$$

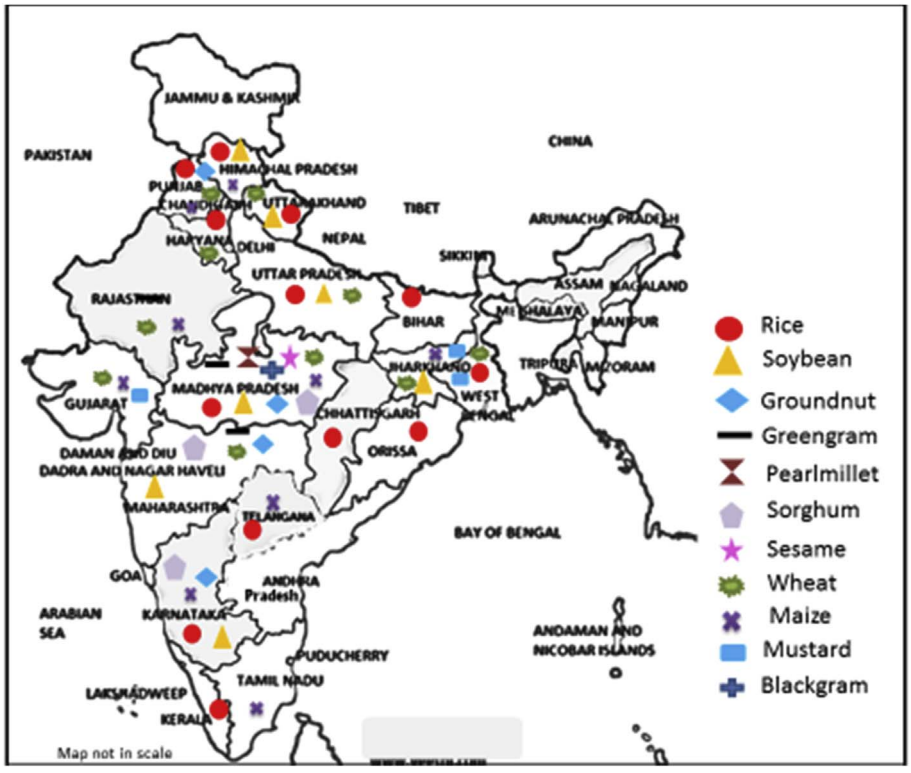

Fig. 1. Map of India depicting the locations (states) of which data were considered for calculation of yield and economic losses due to weeds for different crops given as legends.