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Smart weed management: A small step towards doubling farmers' income

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ABSTRACT

Increasing incomes by reducing crop losses due to various pests and improving productivity and input-use efficiency, are some of the major recommendations of the report on Doubling Farmers' Income by 2022. Weeds are unwanted intruders into agro-ecosystems that compete for limited resources and reduce crop yields and farmers' income. It was estimated that on an average the weed control costs around INR 6000/ha (USD 92.42/ha) in rainy season crops and around INR 4000/ha (USD 61.61/ha) for winter crops, which accounts for around 33% and 22% of total cost of cultivation, respectively. Thus, efficient weed management can help in increasing the farmers' income by reducing the losses caused by weeds, decreasing the cost of production, and increasing the productivity through efficient utilization of resources. The present paper deals with the importance of weeds in crop production and farmers' income, and role of smart weed management practices in reducing cost of production, and improving input-use efficiency and crop productivity.

INTRODUCTION

With a population of 1.35 billion, India is the second most populous country in the world (www.worldometers.info). The population is expected to reach 1.7 billion by 2050, making it as the most populated country in the world. To feed the increasing population food production must increase by 70%. This challenge is critical in view of the declining per capita availability of natural resources, adverse effect of climate change on agricultural production and environment. The low and highly fluctuating agricultural productivity and farm income are causing a detrimental effect on the interest in farming, and farm investment, and forcing more and more farmers, particularly younger group, to leave farming (Saxena *et al*. 2017). It is apparent that income earned by a farmer from agriculture is crucial to address agrarian distress and promote farmers welfare. Realizing the need to pay special attention to the plight of farmers, the Hon'ble Prime Minister of India announced to double the farmers income by 2022 to promote farmers welfare, reduce agrarian distress and bring parity between income of farmers and those working in non-agricultural profession. Increasing incomes by improving productivity and input-use efficiency, and reducing crop losses due to various pests are some of the major recommendations of the report on Doubling Farmers Income by 2022 (Anonymous 2016). The recent budget proposal presented by the Government of India for 2018-19 has provided a number of policy interventions for achieving this goal. This apart, several technologies developed by agricultural scientists over the years are available that aim at reducing the cost of cultivation and increasing the efficiency of various inputs used in crop production. The higher crop productivity thus achieved will result in improved farmers' livelihood. In this paper, an attempt has been made to highlight adoptable weed management technologies with the expectation that our extension system will take them to the farmers.

Losses due to weeds

Weeds are a perennial problem with the farmers. They are omnipresent and reduce yield and quality of crops substantially. Farmers spend a lot of resources to reduce their impact, many a times quite unsuccessfully. In India, the highest loss (33%) is caused by weeds, followed by pathogens (26%), insects (20%), storage pests (7%), rodents (6%) and others (8%) (Kulshrestha and Parmar 1992). Based on the average loss (20%) due to pests as estimated by the Ministry of Agriculture, it approximates to around INR1400 billion (USD 21.56 billion), of which weeds are responsible for more than INR 460 billion (USD 7.09 billion) (Agarwal 2007). Yaduraju (2012) estimated a total economic loss in arable crops equivalent to approximately USD 13 billion per

annum. More recently, in a more scientific study, Gharde *et al.* (2018) reported an annual loss of USD 11 billion in 10 major crops due to weeds alone. In addition to the direct effect on crop yield, weeds result in a considerable reduction in the efficiency of inputs used and food quality. The precious and costly inputs such as fertilizers and irrigation water which are otherwise meant for realizing the potential yield will be usurped by the weeds. Indirectly, weeds interfere with agricultural operations and also act as an alternate host for many crop pests.

Costs of weed control

The data collected from ICAR-Directorate of Weed Research (DWR), Jabalpur show that with the traditional weed control methods, farmers are losing close to 15-20% crop yield and there is a tremendous scope for enhancing crop yield by adopting recommended weed control practices. Weed control is one of the costliest practices in crop production. It has been estimated that on an average the weed control costs around INR 6000/ha (USD 92.42/ha) in rainy season crops and around INR 4000/ha (USD 61.61/ha) for winter crops, which comes to the tune of 33% and 22%, respectively of the total cost of cultivation (**Table 1**) (Commission for Agril. Costs and Prices, Deptt. of Agriculture, Government of India, 2015). Efficient and effective methods of weed control, that are not only efficient but are also cost-effective, are needed as they invariably ensure higher crop productivity and eventually increase the net returns of the farmers. There are opportunities for employing methods, which are not only efficient but are also cost-effective. Such an approach would eventually increase the net returns of the farmers. Large majority of the farmers follow manual and mechanical methods to manage weeds, which are labour-intensive and are often inefficient. The increasing migration of rural population and employment opportunities under several social security schemes have led to serious shortage of labour in agriculture. Data compiled by DWR, Jabalpur of the research carried out at AICRP on Weed Control have shown that weed control using herbicides resulted in significantly more yield over farmer's practice, with nearly one-third saving in the cost on weed control. However, the proven technologies are not yet been fully adopted by the farmers due to a variety of reasons.

Weed management and input-use efficiency

Weeds compete with crop plants for water, nutrients, and sunlight, thereby reducing crop yields and consequently input-use efficiency. Inherently, most weeds accumulate higher concentration of

Table 1. Cost of cultivation *vis-a-vis* weed control

Crops	Cost of cultivation* (INR/ha)	Cost of weed control (INR/ha)	% Share of weed control in total cost of cultivation
Rainy season			
Rice	30070 (463.18)	6500 (100.12)	21.62
Maize	22491 (346.44)	5000 (77.02)	22.23
Sorghum	19358 (298.18)	5000 (77.02)	25.83
Pearl millet	14380 (221.50)	5000 (77.02)	34.77
Pigeonpea	23008 (354.41)	6500 (100.12)	28.25
Greengram	13688 (210.54)	6500 (100.12)	47.55
Blackgram	14410 (221.97)	6500 (100.12)	45.11
Soybean	15913 (245.12)	6500 (100.12)	40.85
Average	19165 (295.21)	5937 (91.45)	33.27%
Winter season			
Wheat	26687 (411.08)	3000 (46.21)	11.24
Chickpea	18875 (290.74)	4500 (69.32)	23.84
Lentil	13941(214.74)	4500 (69.32)	32.28
Mustard	20203 (311.20)	4500 (69.32)	22.28
Average	19927 (306.94)	4125 (63.54)	22.41%

Values in parentheses are in USD. Conversion rate: 1USD=64.92 INR (as on 27th February 2018)

***Source**: Commission for Agril. Costs and Prices, Deptt. of Agriculture, Government of India (2015)

Cost of weed control includes assumption that: use of herbicide +1 manual weeding in *Kharif* crops; and herbicide mixture/ sequential application in wheat; 1 manual weeding in *Rabi* pulses and oilseeds.

nutrients compared to crop plants. There are few weeds like *Amaranthus* spp., which are nitrophilous in nature accumulate more than 3% N on dry matter basis. Similarly, *Anagallis arvensis* and *Achyranthus aspera* contain more than 3.36% phosphorus; and *Chenopodium album* and *Portulaca oleracea* species are known as potassium lovers and contain more than 4.0% potassium on dry weight basis. *Setaria lutescens* accumulates as high as 585 ppm of zinc in its dry matter. This is about three times more than by cereal crops. They also have a unique ability to absorb higher amounts of nutrients in view of deeper and extensive root growth. Thus, poor weed management would amount to diverting of costly inputs for weed growth which are otherwise meant for crop plants. For example; the nitrogen requirements of wheat could be reduced by 67% to produce the same yield if weeds were controlled by applying pre-emergence herbicides (Agrawal and Singh 1985).

Competition for water in a crop-weed situation increases water stress for the crop due to presence of weeds. Some weeds consume more water than crop plants. For example, the consumptive use of water for *Chenopodium album* has been estimated to be 550 mm against 479 mm for wheat (Shahi 1978). The author further noted that the weeds removed moisture evenly from up to 90 cm soil depth, while moisture uptake by wheat was limited to the top 15 cm of soil. In sugarcane, giving irrigation in a weedy

situation increased the cane yields by 1-3 t/ha against 10-28 t/ha increase in weed free plots (Saini *et al.* 1993). The transpiration coefficients 'Q' (the amount of water transpired to produce unit quantity of dry matter) of some of the weeds like *Cynodon dactylon* (813), *Digitaria sanguinalis* (696), *Echinochloa colona* (674), *Tephrosia purpurea* (1108) and *Tridax procumbens* (1402) was higher than that of maize (352) and sorghum (394) (Kanitkar *et al.* 1960). Proper weed control increases available soil water for crop production. The effect of water stress on crop is a function of the developmental stage at which the stress occurs, duration and severity of stress and weed species present. Under weedy situations, plants develop water stress symptoms (*i.e.* lower leaf water potential, reduced leaf stomatal conductance, reduced leaf photosynthesis) earlier than when grown in the absence of weeds, suggesting limited water availability under weedy conditions. This might be due to less developed root systems under weedy conditions, rather than water availability *per se* (Rajcan and Swanton 2001). It is, therefore possible to maintain higher crop productivity and input-use efficiency even under lower levels of nutrient and irrigation by timely and efficient management of weeds.

Weed-crop competition

Untimely weeding and the poor crop stand are believed to be the two major factors responsible for the dominance of weeds. It is to be understood that there is no substitute for timely weeding. Keeping the crop weed free or with minimal weed interference during the critical period of weed competition (CPWC) is of paramount importance. Weed competition during this period causes irreparable loss in crop growth ultimately resulting in lower crop yield. The next factor is the inability of majority of the farmers in raising a good crop. Fryer (1983) stated that '*a good crop is the best weed killer'*. The recommended cultivation practices starting with selection of a crop cultivar, timely planting, optimum seed rate, timely application of fertilizers and irrigation, management of insect pests and diseases, etc., are instrumental in establishing a good crop. Extensive reviews on the role of crop competition in managing weeds can be found in a special issue of Crop Protection (Volume 95, 2017).

The following sections attempts to analyze how each weed control method could be practiced in an ideal way so as to get maximum productivity of crops with relatively lower investment. The objective of this paper is not to review each method extensively but to sensitize the weed science community the vast opportunity of exploring the potential of several such methods- many of them involve least or no additional investment- in achieving effective and economic weed control.

Preventive methods

Prevention is better than control and it is the most cost-effective measure. With less or no extra investment they can be employed to minimize infestation and competition by weeds substantially. However, it is seldom appreciated by the farmers and the extension personnel alike. Some of these methods include the use of weed-free crop seed and farm-yard manure (FYM), use of clean farm machinery, control of weeds along bunds and irrigation canals, preventing weeds from setting seeds, etc. Everyone concerned must be reminded of the old adage *one year seeding is seven years weeding!* Good control of weeds in nursery will ensure transplanting of crop plants free of weed seedlings in the main field. Soil is a big reservoir of weed seeds and perpetuates weed infestation for several years even if one attempts to achieve almost the impossible task of not permitting the addition of fresh weed seeds in to the soil. Several techniques could be employed to reduce the load of weed seed bank in the soil. Readers may refer to Rao *et al.* (2017) for more information on the impact of preventive weed control measures on weed seed bank.

Cultural methods

All production practices followed in raising the crop affect infestation and competition by weeds either directly or indirectly. The practices which encourage crop growth also encourage weed growth. But research has shown that it is possible to manipulate some of the agronomic practices which would have greater impact on crop growth than on weeds. Some of them are the time-tested practices such as crop rotation, summer tillage, stale seed bed preparation, weed competitive crop cultivars, green manuring, mixed/intercropping, intercultural operations, *etc*. Very often such practices require no or minimal additional investments. There is good scope for minimizing the loss of nutrients by resorting to placement of fertilizers nearer to the crop root zone rather than broadcasting. Similarly, the water use efficiency could be enhanced by adopting suitable methods such as, irrigation in the alternate furrows or basin application in wide spaced vegetable, plantation and fruit crops or more desirably through drip irrigation. Such simple nutrient and water management practices often referred to as selective crop stimulation techniques result in significant reduction in the infestation of weeds and enhance input use efficiency. Similarly, intercropping with fast canopy forming crops suppress weed

growth substantially. Enhanced crop competitive ability against weeds has been suggested by several weed scientists for reducing the costs of weed control and as an environmentally-compatible tool for farmers. It has been shown that an investment close to INR 2000-2500/ha could be saved by resorting to zero or minimum cultivation through reduction in cost of land preparation. As a bonus, the technology has been found to decrease the incidence of some of the weeds (for example *Phalaris minor* and *Chenopodium album* in wheat) as well.

Chemical methods

Herbicides offer convenient, easy, flexible and an efficient option of weed control. Due to the fact, the labour is scarce and expensive, chemical weed control is gaining wider acceptability with the farmers. A wide range of herbicides is available to suit all crops and cropping systems to control a diverse spectrum of weeds. They could be applied at planting and during early stages of crop growth and also under adverse soil and weather conditions. There are two ways how the farmers could increase their income through use of herbicides; Firstly, by increasing the herbicide efficacy and secondly by minimizing the crop injury. How this could be achieved is discussed in the following sections.

Increasing herbicide efficiency

Selection of herbicide: Crop is infested with a wide-spectrum of weeds which vary with crop, cropping system, soil, climatic and management conditions. The choice of an herbicide depends on weed flora, time of application, crop rotation and whether the crop is grown sole or intercropped. For any given situation, if there are many herbicides available, it is quite natural to go for an herbicide which is relatively cheaper. Selection also depends on what would be the ideal time of application- either before or after crop emergence. There are a good number of herbicides available for application in most cereals both as pre- and post-emergence. However, the availability of herbicides that could be applied post-emergence in pulses and oilseeds are relatively few.

Herbicide dose: The major consideration for optimal dose is soil type and growing conditions. Light soil with low organic matter content requires lower dose than heavy soils with higher organic matter content. The pre-emergence herbicides perform better when applied to soil with sufficient soil moisture. Hence there is good scope for reducing the herbicide dose in irrigated crops. With post-emergence herbicides, the time of application is more critical. They perform better when applied early. Young and fast growing weeds are more sensitive to herbicide treatment. Ensure optimum soil moisture for maximum effect, stressed plants exhibit resistance to herbicides.

Herbicide application: Unlike other pesticides, the application plays an important role in determining herbicide efficacy. Calibration of the sprayer is must so as to apply the herbicide at the recommended dose over a given area. Choosing the right kind of a sprayer, nozzle and the application pressure are critical in ensuring uniform application. In India, farmers give least attention to application of herbicides. Inappropriate application not only lowers weed control efficiency but may also result in crop injury. More care is required while using spray booms. It is common to see patches of weeds not controlled or patches of crop plants showing phytotoxicity symptoms because of incorrect alignment of nozzles and faulty height of the spray boom. Both these conditions result in poor crop growth and yield.

Use of adjuvants: Most of the herbicides are formulated for ready use by farmers. However, there is scope for improving the efficacy of herbicides by use of adjuvants. Adjuvants increase retention of spray on the foliage and better spreading of droplets thereby increasing the absorption and translocation of the herbicide. For instance, it is well documented that addition of ammonium sulfate enhances the efficacy of glyphosate against many perennial weeds.

Herbicide mixtures: Crop fields are infested with broad-spectrum of weeds. Selective herbicides are known to be effective against a few of them. With continuous use of the same herbicide, the population of weeds which are less susceptible would increase over time. It is therefore ideal to use a mixture of two or more herbicides. Herbicide industry has responded to this concern and has commercialized quite a many 'Ready-mix' herbicides, which are quite popular with farmers. Use of such mixtures provides good control of diverse weeds sustainably for a number of years. Herbicide mixtures are also known to delay the development of herbicide resistant (HR) weeds. Any attempt to delay development of HR in weeds is worth pursuing as managing them later is highly challenging. Alternative herbicides recommended for managing HR weeds would normally be very expensive. It is also a good idea not to use the same herbicide or herbicides belonging to the same group year after year. It is recommended to follow herbicide rotation - meaning alternative use of herbicide(s) belonging to different groups.

Time of application: As has been discussed earlier, targeting the weed at their early growth stage is beneficial. This may entail the use of a lower dose of herbicides. More importantly, better weed control

could be realized by exploiting the soil and weather conditions, which are favourable for increased herbicide activity. A well-prepared seedbed with sufficient soil moisture enhances the efficacy of the pre-emergence herbicides. By and large, higher levels of temperature, relative humidity and solar radiation enhance the activity of many herbicides applied post-emergence. Greater herbicide efficacy could be achieved by coinciding herbicide application with such weather parameters. Rainfall however has the maximum impact. Herbicide application is to be avoided, if rain is expected within the next 2-4 hours of application. The interval, however, may vary from herbicide to herbicide. Paraquat, for instance, is known to control weeds effectively even if it rains within 15 to 30 minutes of spraying.

There has been contrasting reports with regard to what time of the day the herbicide be applied for better weed control. Early morning hours are generally considered ideal for herbicide spray as there is less wind. Heavy wind encourages spray drift. Spraying paraquat towards the end of daylight hours on a cloudy day is reported to boost the efficacy. These usually result in longer lasting weed control. A group of weed scientists from several universities from the USA have observed that glyphosate application made at 5.00 AM resulted in 16% control of glyphosate-resistant *Amaranthus palmeri* as compared to 56% when applied at 11.00 AM. (http://www.southeastfarmpress.com/cotton/herbicides-time-day-you-spray-can-make-difference). Almost similar results were noticed with glufosinate, 2,4-D and dicamba. Therefore, it is worth exploring the opportunities for increasing the efficacy of herbicides by timing the herbicide application.

Conclusion

It may be stated that there is enormous scope for enhancing the farmers income by lowering the cost on weed control and by achieving higher productivity. Timely weeding and raising a healthy crop are critical in our fight against the onslaught of weeds. A number of preventive and cultural methods and minor changes in agronomic practices have a very significant bearing on weed competition. Several of these involve no or insignificant additional expenditure. The impact of these practices may not appear significant when followed individually, but will have a substantial effect when more than one are integrated and followed collectively. Herbicides by virtue of their merit will be an important component of Integrated Weed Management (IWM). With judicious use and clever integration with other methods of weed management, herbicides will enable farmers to achieve better weed control at reduced cost and very often with enhanced productivity of crops. However, IWM being a knowledge intensive activity requires the support and patronage of weed scientists and extension personnel. Farmers need to be sensitized in popularizing the benefits of the technology. Every effort must be made to prevent the introduction of new weeds. One should be particularly wary of invasive weeds, perennial weeds and parasitic weeds as they are known for their competitive ability, elasticity and resistant to weed management strategies. Periodical scouting of the field for new introductions and their eradication, if found, therefore assumes significance.

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