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Integrated Weed Analysis Management in Maize: A Review

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Abstract

Effective weed control in corn (*Zea mays* L.) is important to optimize yield. Excluding environmental variables, yield losses in corn are caused mainly by competition with weeds. Weed interference is a severe problem in maize, especially in the early part of the growing season, due to slow early growth rate and wide row spacing. Weeds compete with the maize plants for resources such as light, nutrients, space, and moisture that influence the morphology and phenology of crop, reduce the yield, make harvesting difficult, and mar the quality of grains. In order to realize the yield potential of maize, weed management becomes indispensable. Weed species infesting the maize crop are functions of a complex interaction among soil characteristics, climate, and cultural practices. A number of weed species compete with corn plant and have been observed to reduce yield as much as 30%-93% with delay in weed control. Weed species, densities, and their interactions influence maize yield loss. Effective weed management continues to be important in obtaining optimum corn yields.

Integrated Weed Management is an important component of Integrated Pest Management (IWM), which is a holistic approach to sustainable agriculture focusing on managing insects, weeds and diseases through a combination of physical, cultural, biological and chemical measures that are cost effective, environmentally sound, and socially acceptable. A successful IWM program must include prevention of weeds from invading, knowing the identity and details of the weed species, mapping its distribution and damage, formulating control strategy based on knowledge of potential damage, cost of control method, and environmental impact of the weed, using a combination of control strategies to reduce the weed population to an acceptable level, and, finally, evaluating its effectiveness. All those weed management strategies are typically grouped into five categories: Preventive, cultural, mechanical (physical), biological, and chemical. No weed management technology used alone is sustainable since weeds will adapt to any single tactic used repeatedly for many years. Therefore, an IWM approach is required for sustainable corn production to meet the growing demand.

Keywords: Integrated weed management; Cultural Mechanical; Chemical; Weed management

Introduction

Maize is one of the most important cereal crops in the world. It ranks third position among other cereals after wheat and rice. According to, 690.7 million tons of maize was produced on 135.4 million hectares worldwide, with a yield of over 5.1 tons ha^{-1} in 2012. Maize is the most important cereal crop in eastern and southern Africa accounting for over 29% of the total harvested area of annual food crops and 25% of total caloric consumption. Maize introduced to Ethiopia during the 1600's to 1700's by Portuguese traders. Since then, it is a major crop in terms of production, consumption and income generation for resource constrained men and women. In Ethiopia, currently maize grows in all parts of the country with major maize growing belt concentrated in western, south-western, southern regions and eastern highland of Hararghe. It grows under different agro-ecologies ranging from lowland to the highland areas. It is the major and staple food and one of the main sources of calorie in the major maize producing regions. In 2014/15 cropping season, about 2.1 million hectares of land was covered with maize with an estimated production of about 7.23 million tons. It accounts for 16.80% of the 10.14 million ha (80.78%) of land allocated for all cereals. It ranks second after teff (*Eragrotis* tef) in area coverage, first in total national production and yield per hectare.

Excluding environmental variables, yield losses in corn are caused mainly by competition with weeds. Weed interference is a severe problem in corn, especially in the early part of the growing season, due to slow early growth rate and wide row spacing. Weeds compete with the corn plants for resources such as light, nutrients, space, and moisture that influence the morphology and phenology of crop, reduce the yield, make harvesting difficult, and mar the quality of grains. Furthermore, high weed infestation increases the cost of cultivation, lowers value of land, and reduces the returns of corn producers. In order to realize the yield potential of corn, weed management becomes indispensable. Weed species infesting the corn crop are functions of a complex interaction among soil characteristics, climate, and cultural practices. These factors vary across regions and influence the composition and number of predominant weeds of economic importance to maize production.

Effective weed management continues to be important in obtaining optimum corn yields. Integrated Weed Management (IWM) is an important component of Integrated Pest Management, which is a holistic approach to sustainable agriculture focusing on managing insects, weeds and diseases through a combination of physical, cultural, biological and chemical measures that are cost effective, environmentally sound, and socially acceptable. The goal of a weed management program should be to keep the competition offered by weeds under check and not the complete removal or eradication from the ecosystem.

To achieve this, a comprehensive action plan utilizing preventive methods, scientific knowledge, management skills, handling capacity monitoring procedures, and efficient use of control practices should be devised, making conditions unfavorable to the weeds and their survival. A successful IWM program must include prevention of weeds from invading, knowing the identity and details of the weed species, mapping its distribution and damage, formulating control strategy based on knowledge of potential damage, cost of control method, and environmental impact of the weed, using a combination of control strategies to reduce the weed population to an acceptable level, and, finally, evaluating its effectiveness. The objective of this review paper is to discuss the various integrated weed management strategies for the control of noxious weeds in Maize crop for sustainable agriculture.

Literature Review

Based on their importance, elements can be essential (such as K, Mg, Ca, Mn, Fe, Co, Cu and Zn) and they are very important for growth and health, or they may be non-essential (such as Cd, Ag and Pb). Based on the amount needed nutritionally minerals are grouped into macro-minerals and trace. Elements such as Mn, Fe, Co, Cu, Zn, Se, Mo, F and I are essential trace elements, while elements like Ca, Mg and K are grouped under essential macro elements [5].

Macro-nutrients, micronutrients and toxic elements

These metals are required by body in good quantities for proper metabolism and functioning of body organs. These include calcium, magnesium, sodium and potassium. Micronutrients are needed in very small amounts. Their adequate concentrations in plants are generally below the 100 parts per million levels. The essential micronutrients are zinc, iron, manganese, boron, chlorine, copper, molybdenum, cobalt, vanadium, silicon, nickel Heavy metal is the generic term for metallic elements having an atomic weight higher than 40.04 [6]. Plants are sensitive to environmental conditions and they accumulate these heavy metals in their harvestable and intensity of this uptake process can change the overall elemental composition of the plant. Some of the heavy metals namely Pb, Cd, As and Hg are not essential for plants and these are insidiously toxic to mammals [7].

Equipment

Polyethylene plastic bags were used to pack the soil samples. A drying oven was used to dry soil samples. A digital analytical balance with ± 0.0001 g precision was used to weigh soil samples. 250 mL round-bottomed flasks fitted with reflux condensers were used in Kjeldahl (England) apparatus to digest the dried and powdered soil samples [8]. A refrigerator (Hitachi, Tokyo, Japan) was used to keep the digested sample until analysis. Agilent model 4200 (USA) Microwave Plasma Atomic Emission Spectroscopy (MPAES) was used for analysis of the metals (K, Mg, Ca, Fe, Mn, Zn, Cu, Pb, Cd).

A ceramic mortar and pestle (USA) was used for grinding and homogenizing the soil samples. Conductivity meter and pH meter (Romania) were used for measuring electrical conductivity and pH of the soil samples [9].

Reagents and chemicals

Reagents used in the analysis were all analytical grade. (69%-72%) HNO_3 (Spectrosol, BDH, England) and 70% $HClO_4$ were used for digestion of soil samples. Strontium nitrate (98%, Aldrich, Muwaukee, USA) was used to avoid refractory interference (for releasing calcium and magnesium from their phosphates). Stock standard solutions containing 1000 mg/L, in 2% HNO_3, of the metals K, Mg, Ca, Fe, Mn, Zn, Cu, Pb and Cd (Buck Scientific Puro-Graphictm) were used for the preparation of calibration standards and in the spiking experiments. Distilled water was used throughout the experiment for sample preparation, dilution and rinsing apparatus prior to analysis [10].

Apparatus

Apparatus such as volumetric flasks, measuring cylinder and digestion flasks were washed with detergents and tap water and rinsed with distilled water and soaked in 50% nitric acid for two days. They were then rinsed with distilled water three times and dried in an oven and kept in dust free place until analysis begins.

Description of sampling sites

The soil samples were collected from the most teff productive areas of three different localities of Amhara regional state of Ethiopia. Particularly from Bahir Dar, Bure and Debre Markos, which are located in the north western part of Amhara regional state. The geographical locations (latitude, longitude and elevation) of sampling sites are described as follows. Bahir Dar is located at a latitude of $11^{o}35'37.1''$ N and longitude of $37^{o}23'26.8''$ E in the Northern hemisphere [11-15]. Bahir Dar is located at the exit of the Abbay from lake Tana at an altitude of 1,820 meters above sea level. The city is located approximately 578 km north-west of Addis Ababa. Debre Markos is a city in north-west of Ethiopia. It is located in the Misrak Gojjam Zone of the Amhara administrative region, it is located at a latitude and longitude of 10°20′N 37°43′E coordinates and an elevation of 2,446 meters above sea level. Debre Markos is located approximately 306 km far apart from Addis Ababa [16-20]. Bure is a town in western Ethiopia located in the Mirab Gojjam Zone of the Amhara region, this town is located at a latitude and longitude of 10°42′N 37°4′E with an elevation of 2091 meters above sea level. Bure is located approximately 414 km far apart from Addis Ababa. The reason for selection of these places was based on the availability of the teff and its popularity in consumption.

Sample collection and preparations

The soil samples were collected from the base of the uprooted plant by auger and properly labeled and packed in polyethylene bags. Each soil sample was air dried at ambient temperature for three days and then ground into powder using acid washed commercial mortar and pestle and sieved to 0.425 mm mesh. The sieved soil samples were stored in the polyethylene bags and placed in desiccators until the time of digestion [21,22].

Soil pH determination

Soil pH was measured in a suspension (1:2.5, w/v) of the soil and distilled water. 5 g of air-dried soil (<0.425 mm) was weighed and transferred to a 100 mL beaker into which 12.5 mL distilled water was added. Then, the mixture was stirred and the pH was measured after allowing the suspension to stand for 10 min at room temperature [23].

The electrical conductivity determination

The electrical conductivity of the soil samples was measured in suspension (1:2.5 w/v) of the soil distilled water. 5 g of air-dried soil (<0.425 mm) was weighed and transferred to a 100 mL beaker into which 25 mL distilled water was added. The mixture was stirred and allowed to stand for 15 min at room temperature and the electrical conductivity was measured.

Soil organic matter determination

Soil organic matter content was determined using the method of loss on ignition. 5 g of the soil sample, which was dried in an oven at 100°C for 15 min was accurately weighed into a pre-weighed crucible. Then the crucible with soil was placed in a muffle furnace and heated at 500°C for 3.5 h. The sample was then taken from the furnace and placed in desiccators to cool. Then the sample was reweighed and the percentage of organic matter content was calculated [24-28].

Optimization of the digestion procedure for soil samples

A 0.5 g of crushed, powdered, sieved and homogenized soil samples were weighed and transferred to a 250 mL round bottom flask. Different digestion procedures were carried out for the teff samples using HNO_3 and $HClO_4$ acid mixtures by varying volume of the acid mixture, digestion time and digestion temperature. Optimized procedures were selected based on the usage of lesser reagent volume, shorter digestion time and reasonable mild temperature for obtaining clear and colorless solutions of the resulting digests. Based on this fact the optimized digestion conditions for the soil samples in this study were (5 ml HNO_3: 1 mL $HClO_4$) volume ratio of reagents, 240°C digestion temperature and 2:30 h digestion time and are shown in (Table1).

Trials	Reagent volume (mL)			Temperature (°C)	Time (h)	Results
	HNO_3	$HClO_4$	Total			
1	1	1	2	240	0.104167	Yellow with suspension
2	2	1	3	240	0.104167	Cloudy yellow
3	3	1	4	240	0.104167	Nearly colorless
4	4	1	5	240	0.104167	Slightly colorless
5	5	1	6	240	0.104167	Clear colorless
6	6	1	7	240	0.104167	Clear colorless
7	3	2	5	240	0.104167	Slightly colorless
8	4	2	6	240	0.104167	Nearly colorless
9	4	1	5	240	0.104167	Nearly colorless
10	5	2	7	240	0.104167	Clear colorless
11	5	1	6	240	0.020833	Yellow with suspension
12	5	1	6	240	0.041667	Yellow with suspension
13	5	1	6	240	0.0625	Cloudy light yellow
14	5	1	6	240	0.083333	Light yellow
15	5	1	6	240	0.104167	Clear colorless
16	5	1	6	240	0.125	Clear colorless
17	5	1	6	150	0.104167	Cloudy yellow with suspension
18	5	1	6	180	0.104167	Cloudy yellow with suspension
19	5	1	6	210	0.104167	Slightly yellow

20	5	1	6	240	0.104167	Clear colorless
21	5	1	6	270	0.104167	Clear colorless
22	5	1	6	300	0.104167	Clear colorless

Table 1: Reagent ratios and volumes, temperature and time attempted during optimization of digestion of 0.5 g of the soil sample.

The digested solutions were allowed to cool and 5 mL of distilled water was added to dissolve the precipitate formed on cooling and gently swirled and filtered into 50 mL volumetric flask through Whatman no. 42 filter paper. The clear solution then was diluted up to 50 mL with distilled water and stored until analysis by microwave plasma atomic emission spectroscopy [29,30].

Digestion of the soil samples

0.5 g of crushed, powdered, sieved and homogenized soil samples were weighed and transferred to a 250 mL round bottom flask. To this, 5 mL of HNO_3 and 1 mL $HClO_4$ were added. The digested solutions were allowed to cool and 5 mL of distilled water was added to dissolve the precipitate formed on cooling and gently swirled and filtered into 50mL volumetric flask through Whatman no. 42 filter paper. The clear solution then was diluted up to 50 mL with distilled water [31]. Each soil samples were digested in triplicate. Digestion of a reagent blank was also performed in parallel with the samples. The solutions were used for the analysis of the soil metal concentrations for K Ca, Mg, Fe, Cu, Zn, Mn, Pb, and Cd by Microwave Plasma Atomic Emission Spectroscopy (MPAES) [32-36].

Results and Discussion

The values of soil pH, % SOM and EC of the soils of the three different places were presented in. The results of each soil's pH,%SOM and EC are discussed below (Table 2).

Sampling site	pH ± SD	EC ± SD (mS/m)	SOM ± SD (%)
Bahir dar	6.48 ± 0.34	71.4 ± 0.40	17.7 ± 0.37
Bure	6.95 ± 0.07	51.1 ± 0.50	11.9 ± 0.96
Debre Markos	6.92 ± 0.05	18.4 ± 0.97	13.3 ± 0.18

Table 2: The value (mean ± Standard Deviation (SD), n=3) of pH, electrically conductivity (mS/m) and organic matter (%) of the soil.

The higher the soil organic matter content, the higher the ability of that soil to retain metals within it. The result of the analysis showed that the highest % soil organic matter was obtained in the soil collected from Bahir Dar followed by that of Debre Markos and the lowest was obtained in the soil Bure. So based on the result, the metals are more retained in the soil of Bahir Dar. Therefore, the bioavailability of metals in the soil for the plant species becomes low when the organic content of the soil is high due to the adsorption reaction of metals on it [37].

Most plants grow best in slightly acidic soils (pH 6.0-7.0). In this pH range, nearly all plant nutrients are available in optimal amounts. Soils with a pH below 6.0 are more likely to be deficient in some available nutrients. Ca, Mg, and K are especially deficient in acid soils. Metal solubility tends to increase at lower pH and most of the mobility of metals is reduced with increasing soil pH because of the precipitation as insoluble hydroxides, carbonates and organic complexes. Usually, the intensity of root uptake of metal by plants decreases with increasing soil pH. Low soil pH value determines the activity of many metal ions in the water contained in the pores of the soil, affecting their bioavailability. The result showed that the soil pH for the three study areas is within the range of 6.48-6.95, which categorizes the soils under weakly acidic soils. According to most plants grow best in this pH range [38,39].

Soil Electrical Conductivity (EC) is a useful indicator in managing agricultural systems. EC directly affects plants growing in the soil or media. EC range of 0 mS/m-100 mS/m indicates good soil health. Soils that have EC of less than 100 mS/m is considered to be nonsaline. Soil that has EC of more than 100 mS/m is considered to be saline. Important microbial processes such as nitrogen cycling, production of nitrous gases and other N oxide gases, respiration and decomposition of organic matter are affected. Populations of parasitic nematodes and loss of nitrogen can be higher in these soils [18]. The result showed that the soil EC of the three study areas were within the range of 18.4 to 71.4 mS/m, indicating that soil environment is good for the plant growth. EC does not provide a direct measurement of specific ions or salt compounds; it has been correlated to concentrations of nitrates, potassium, sodium, chloride, sulfate and ammonia [40,41].

In general, loading, and accumulation of metals in the soil depend on different factors such as the chemical form of elements, pH, organic matter content, texture and Cation Exchange Capacity (CEC) of the soil. With increasing pH, organic matter content, CEC and clay, the percentage and availability of the metals are reduced. In addition, the existence of carbonate, sulfate and phosphate and sulfide in the soil creates an increase in the metal precipitation and consequently decrease their availability to the plants [42-44].

Calibration of the instrument

Calibration curves were prepared to determine the concentration of metals in the sample solution. The instrument was calibrated using four series of working standards. The calibration graphs and correlation coefficients of each of the elements were determined by plotting working standards concentration of metals versus their corresponding emission intensity [45].

Evaluation of analytical method

Recovery is one of the most commonly used techniques utilized for validation of the analytical results and evaluating how far the method is acceptable for its intended purpose. The validity of the digestion procedures were assured by spiking the samples with a standard solution of known concentration of the target analytes and the percentage recoveries lies from 92%-104%, which were within the acceptable range. The spiked soil samples were digested in triplicate following the same procedure used for digestion of the fruit and the soil samples. The resulting digest of the spiked samples was analyzed for their respective metal contents using MP-AES and percent recoveries were calculated for the soil samples [46].

Level of metals concentration in the soil samples

Metals may enter the human body through inhalation of dust, direct ingestion of soil and consumption of food plants grown on metal contaminated soil.

The most important pathway through which human exposure to metals takes place is soil-plant-human (food chain) and soil human (incidental soil ingestion) relationship. Out of the two soil- to-plants transfer are the key components of human exposure to metals. Therefore, analyses of the level of metals in soil are important.The results of the analysis for the soil samples are given in Table 3.

Sampling sites	Mean concentrations of the metals (mg/kg)								
	K	Mg	Ca	Mn	Fe	Cu	Zn	Pb	Cd
Bahir Dar	3701 ± 3	1202 ± 2	6201 ± 2	1449 ± 1	69714 ± 3	28.1 ± 3	132 ± 1	3.10 ± 0.4	1.09 ± 0.1
Bure	3635 ± 2	1109 ± 1	2189 ± 3	1023 ± 6	75823 ± 3	56.9 ± 2	155 ± 3	4.33 ± 1.0	2.15 ± 0.3
Debre Markos	3366 ± 4	1408 ± 1	5062 ± 4	1115 ± 2	76731 ± 2	30.5 ± 1	168 ± 2	5.25 ± 0.3	3.14 ± 0.2
Overall mean	3567 ± 3	1239 ± 1	4484 ± 3	1196 ± 3	74089 ± 3	39.0 ± 2	152 ± 2	4.20 ± 0.6	2.10 ± 0.2

Table 3: Mean concentration of metals (mg/kg), (mean ± SD, n=3) in the soil samples.

As shown in Table 3, the results showed that the mean concentration of the Fe content of the soils is the highest of all the other studied metals in all of the three sampling areas. The overall mean concentrations of the metals collected from the three sampling areas in mg/kg can be ordered as Fe (74089 ± 3)>Ca (4484 ± 3)>K (3567 ± 3)>Mg (1239 ± 1)>Mn (1196 ± 3)>Zn (152 ± 2)>Cu (39.0 ± 2)>Pb (4.20 ± 0.6)>Cd (2.10 ± 0.2). On the other hand, the soil samples were not free from the level of the toxic heavy metal Pb and Cd ranges from 3.10 mg/kg-5.25 mg/kg of Pb and from 1.09 mg/kg-3.14 mg/kg of Cd collected from the three sampling areas. This may be caused due to different agricultural practices like the usage of fertilizers [47].

Statistical analysis

Statistical method was used to check whether there is a contribution from the random errors for the difference in results of analysis or not. If there are differences, statistical analysis will tell us whether the differences are significant or not at a specified confidence level. One-Way Analysis of Variance (ANOVA) was used to perform the statistical analysis soil samples as independent and concentration of the metals as a dependent variable to test whether there are significant differences between means of each soil samples collected from the three sampling areas. There was a significant difference between the metal concentrations of the soils collected from the three sampling areas at a confidence level of 95%.

Conclusion

The levels of essential and trace metals (K, Ca, Mg, Fe, Zn, Cu, Mn, Pb and Cd) in the soil samples collected from the three samplingareas were determined by using MP-AES. The study showed that the metals were present at different concentrations in the samples from different sites. Comparable results were found with some of the values reported in the literature and for Cd and Pb metals; the concentrations slightly exceeded the permissible levels by WHO/FAO, which could be attributed to the agricultural practices employed such as the use of fertilizers and herbicides. In this study soil pH, soil organic matter and soil electrical conductivity were also determined. Therefore, this study will give brief information about the essential and trace metals of the soil samples collected from the three different sampling areas.

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