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Survey of Weed Flora in Sugarcane (*Saccharum officinarum L.*) at Arjo Didessa Sugar Estate, Western Ethiopia

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Abstract

Weeds are the major ecological and economic pest in Ethiopia. A Survey of weed flora in sugarcane was conducted at Arjo Didessa sugar estate to assess weeds in sugarcane plantation fields. It was carried out on 40 fields of the sugarcane plantation farm. The fields were stratified into two soil types (luvisol and vertisol). The soil groups were further stratified into plant cane and ratoon cane. Then, the plant and ratoon canes were further stratified into sugarcane cultivars; NCO334 and N14. Two to five fields were surveyed in each stratum and a total of 420 samples were collected. The survey was made at the early growth stages (25-30 days after planting) for plant cane and one week before fertilization for ratoon cane fields using 0.25m2 quadrat following a pattern of inverted "W" continuously for every 2.5-3 ha. Weed plants in each quadrat were collected and identified species-wise. The result showed 169 weed taxa belonging to 34 families. The most abundant families that account for 84.62% of the total weed species were: Gramineae, Compositae, Fabaceae, Cyperaceae, Convolvulaceae, Solanaceae, Euphorbiaceae, Amaranthaceae, Malvaceae, Commelinaceae, Cucurbitaceae, and Liliaceae. Similarity indices of two soil types, two sugarcane crop types, and two sugarcane cultivars varied from 35.23% and 59.05% indicating differences in weed community between all strata. Therefore, the planning of weed control strategy should treat all stratus separately using different control methods.

Keywords: Weed survey; Weed flora; Western Ethiopia; Sugarcane; Arjo Didessa

Introduction

Ethiopia is a country located in East Africa has a conducive environmental conditions and land for the production of sugarcane plantation. Sugarcane (*Saccharum officinarum* L.) is a perennial tropical grass (Poaceae) that originated in South East Asia (Singh et al., 2015). It is the main sugar-producing crop that contributes nearly 75% of the total sugar pool at the global level (Solomon, 2016). Sugar cane is a C4 photosynthetic pathway that is physiologically very efficient in harvesting the sunlight that is converting solar energy into sugar and fiber (Gupta, 2009). The ability to accumulate high sucrose concentration in the harvested stem is the net result of sucrose synthesis and breakdown (Siswoyo et al., 2016) [1].

In Ethiopia, the sugar industry plays a great role in creating job opportunities and economic increment. Thus, the government of the country has emphasis to develop new projects and expanding the existing sugar factories. On the other hand, the yield of sugarcane is bounded by many factors such as weeds, diseases, insects, cropping practices, and climatic conditions that constrain sugarcane growth, yield, and quality to a larger extent (Srivastava and Rai, 2012). Weeds are probably the most ever-present class of crop pests and are responsible for marked losses in crop yields (Rana, SS. and MC, Rana, 2015) [2].

Weeds cause more economic loss in Ethiopia's sugarcane plantation than all other pests combined. They are constant problems in the agro-ecosystems and different control methods have been used to control them in different crops (Bajwa, 2014). Weeds can reduce sugarcane yields by competition for light, water, and nutrients, harboring insects and rodents, and interfering with milling (Singha, 2002). The author also indicated that weeds affect the growth and loss of tonnage, reduce sucrose recovery in the mill, and limit the number of ratoon crops.

A weed survey plays a key to generate information that can be used in developing an appropriate weed management strategy. Weed growth, abundance, and distributions vary from place to place depending upon soil and climatic factors and farmers' management practices (Altieri et al., 2015). Therefore, a survey of weed flora composition, distribution, and level of infestation is essential for a comprehensive understanding of the weed problem that poses negative impacts on crop production in a given area (Getachew et al., 2019). The assessment of the nature of weed flora determines, to a large extent, the type of weed management measures to be adopted. Hence, identification, characterization, and quantification of weed species in a specific area are important steps to be followed to design an effective weed control measure [3].

So far, there is no research information available in Arjo Didessa Sugar Estate regarding the weed species composition, their abundance, and distribution in the sugarcane production field. Considering weed composition variability from one location to another and the inadequate research information on weed species composition and their quantitative measurements in the estate. Therefore, this study was carried out to assess the weed species composition, determine their frequency, abundance, and distribution, and identify priority weed problems for improved weed management options in a sugarcane plantation [4].

Materials and Methods

Description of the study area

The sugarcane fields survey was carried out at Arjo Didessa Sugar

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Estate which is located in East Wollega and Buno Bedele Zones of Oromia Region, Ethiopia within the geographic boundaries of 8°20' to 9°0' N latitude and 36°22' to 36°40' E longitude at an average elevation of 1350 meters above sea level, and at a distance of 395 Km on Addis Ababa to Nekemtie and Bedele route. It can also be accessed from Addis Ababa through the Jimma, Bedele, and Nekemtie route at a distance of 540 Km [5,6].

Climatic conditions

The area receives an average annual rain fall of 2002 mm falling with unimodal distribution pattern lasting over the period of May to October and with annual average maximum and minimum temperatures of 30.85°c and 18.43°c, and mean temperature of 24.64°c. The relative humidity of the area is ranging from average maximum of 92.92% to average minimum of 65% with an average of 79%.

Survey of weed flora procedures

A Survey of weed flora was conducted in Vertisol and Luvisol during the on and off-season (May to March) of 2019/20 on the representative farms in Arjo Didessa Sugar plantation farms. The purposive sampling technique was used with a proportional allocation of the stratum. The survey was carried out following a pattern of inverted 'W' as suggested by Thomas (1985) by continuously using 50 x 50 cm (0.25 m2) quadrat for every 2.5-3 ha. The number of samples per hectare was determined by species-area curve and site condition as suggested by Taye and Yohannes (1998). A quantitative assessment method was used for the enumeration of weeds [7].

The plantation fields of the site were stratified into soil types (Vertisol and Luvisol). The soil types of the estate were further stratified into plant cane and ratoon cane. The ratoon crops were again stratified according to their ratooning stages into the first and last ratoon stage (Firehun and Tamado, 2007). Then, the plant and ratoon cane types were further stratified into prominent sugarcane cultivars of the plantation. Two to Five fields were surveyed in each stratum as per the accessible condition [8].

The survey was made during 25-30 DAP for sugarcane plant cane and a week before fertilization for the sugarcane ratoon fields. This period was chosen to overcome the intervention occurs due to weed management practices in the fields. Observations were recorded using quadrates (0.25m2) before human interference with weeds. The first quadrat sample was taken following the procedure of Kevine et al. (1991) and Taye and Yohannes (1998) where the surveyor walks 50 paces along the edge of the field, then turned right angle and walk 50 paces into the field, and quadrat sample started at that point in all fields [9].

During the survey, all the weeds present in each quadrant were removed, collected, and kept separately in polythene bags for species-wise separation, identified, and counted. For perennial grass weeds or herbaceous species, the number of shoots rather than the number of plants were counted. But, for annual grasses, the tillered annual grass (rooted individuals) was counted as a single plant regardless of the number of tillers.

The weeds were identified to species level using the available weed identification guides (Stroud and Parker, 1989; Noel, 2001; Caton et al., 2010; Naidu, 2012; John, 2015; Arne & Quentin, 2017), counted, and recorded per each m2 area. Nomenclature of the available weed species was also made following the flora of Ethiopia and Eritrea, volumes 2, 3, 4, 6, and 7 (Edwards et al., 1995, 1997; Hedberg and Edwards, 1989, 1995; Hedberg et al., 2003). Weeds that were difficult to identify were pressed and tagged on hard papers and then submitted to Addis Ababa University for identification [10,11].

Data analysis

The data on the weed survey was organized and summarized as frequency, relative frequency, abundance, dominance, importance value index, and similarity index values of the identified weeds. They were calculated using the formula described by Taye and Yohannes (1998) with little modification.

Frequency (%): is the percentage of sampling plots on which a particular weed species have found in a field. It shows how often a weed species occur or have distributed in the survey area [12].

$$\text{Frequency} = \frac{\text{Total number of quadrats in which the species occur}}{\text{total number of quadrats studied was}} \times 100$$

Relative frequency (%): expressed as a percentage, is the degree of dispersion of individuals of the target species in the sampling unit concerning the number of all the species that occurred.

$$\text{Relative Frequency} = \frac{\text{Frequency of individuals of a species}}{\text{total frequency of all species}} \times 100$$

Abundance: The population density of a weed species has expressed as the number of individuals of weed plants per unit area.

$$\text{Abundance} = \frac{\text{Total number of individuals of species in all quadrats}}{\text{Total number of quadrats in which the species occurred}}$$

Dominance (%): the abundance of an individual's weeds species concerning total weed abundance.

$$\text{Dominance} = \frac{100 \times A}{\sum A}$$

Where, **A** = abundance, **ΣA** = total abundance of all species

Similarity index: Similarity of weed communities between any two different locations, soil types, surveys, and crop stages in terms of weed composition.

$$\text{Similarity index} = \frac{100 \ \times EPg}{(EPg + Epa + EPb)}$$

Where, Epg = number of species found in both locations, Epa = number of species found only in location a, Epb = number of species found only in location b.

Importance value index: Determines the importance of plant species composition and distribution in a community.

$$\text{Importance value index} = (2 * D) + RF$$

Where, D= Dominance, RF = Relative frequency

All the collected data of the survey have calculated and tabulated using MS-Excel.

Results and Discussion

Weed flora composition and diversity

A Survey of weeds on Arjo Didessa Sugarcane plantation farms showed a total of 169 weed species belonging to 100 genera within 34 families. The weed species were collected and identified from fields of the plantation at different strata. The list of weed species and their characteristic classes presented [13].

This finding is agreement with the result of Taye (1991) reported 143 weed species belong to 37 families in his survey of weed flora in sugarcane fields of Wonji-Shoa and Metahara. It is also in agreement with the result obtained by Firehun and Tamado (2007) which indicated a total of 180 weed taxa belonging to 40 families in Wonji-Shoa and Metahara sugarcane plantations. Also, Takim and Amodu (2013) surveyed sugarcane fields and found a total of 51 weed species belonging to 40 genera within 16 families in the sugarcane fields of Ilorin district, Nigeria. Moreover, the result is similar to a study by Welday et al. (2018b) that showed 145 weed species belonging to 31 families and 93 genera in their weed flora survey in sugarcane fields of Tana Beles [14].

Based on their life cycles, 43% of the weed species in the survey were perennials while 57% of them were annuals. The higher numbers of annual weed species than the perennial weed species might be due to late weeding at which most of the annual weeds were abundantly grown.

This result agreed with Torresen et al. (2003) and Karar et al. (2005) who reported that weed flora on most irrigated farms consists of both annuals and perennials. Similarly, Yohanna et al. (2014) and Welday et al. (2018b) reported annual weeds to have the highest number of species followed by perennials [15].

Based on their morphological classification, 114 (68%) of the weed species in the study area were broad-leaved, 43 (25%) grasses, and 12 (7%) sedges. This result is also in agreement with the result of Welday et al. (2018b) who reported 99 weed species (67%) broad-leaved followed by 40 species of grasses (27%) and sedges with 9 weed species (6%) in their weed flora survey. However, contradicting this result, Yohanna et al. (2014) reported that grasses were recorded with the highest number of species followed by broad leaves and sedges, respectively.

The survey also indicated that dicotyledonous species (68%) were more dominant than monocotyledonous (32%) in the plantation estate. This might be due to improper land preparation of the fields. Our study is supported by the report of Hyvonen et al. (2003) who indicated low input cultivations expected to favor the species numbers and abundance of dicotyledonous weeds [16].

Plant families in the survey area enclosed one up to 43 weed species. Out of 34 families, 18 were monotypic, viz., and contained only one species. These are Acanthaceae, Amaryllidaceae, Aizoaceae, Apiaceae, Asclepeidaceae, Caryophyllaceae, Chenopodiaceae, Labiatae, Nyctaginaceae, Onagraceae, Papaveraceae, Portulacaceae, Ranunculaceae, Tiliaceae, Typhaceae, Umbelliferae, and Zygophyllaceae. Among these, Apiaceae, Papaveraceae, Tiliaceae, and Zygophyllaceae were also reported as monotypic weed families in India as reported by Nigaraju et al. (2014) [17].

Determined by the number of taxa contained, nine dominant families were identified such as Gramineae (43), Compositae (25), Cyperaceae (12), Fabaceae (12), Convolvulaceae (11), Solanaceae (10), Euphorbiaceae (8), Amaranthaceae (6), and Malvaceae (6) which comprised a total of 133 weed species and accounted for 78.69% of the total weed flora. The grass family constitutes a high number of taxa which might be due to the high seed bank of soil in the plantation fields, some have a mimicry nature and are in the same family as sugarcane [18].

In line with this study, Poaceae, Asteraceae, Fabaceae, and Euphorbiaceae were also reported as major weeds that accounted for 54% of the total weed flora in the Wonji-Shoa sugarcane plantation site (Firehun and Tamado, 2006). A similar finding was also reported by Firehun et al. (2008) in the Finchaa sugarcane plantation of Ethiopia in which Poaceae (Graminae), Fabaceae, Asteraceae (Compositae), Euphorbiaceae, and Convolvoceae were the dominant families that accounted for 51% of the total weed families in the area. Similarly, Takim and Amodu (2013) reported Poaceae as the dominant family in sugarcane fields of Nigeria. Welday et al. (2018b) also reported that the dominant weed species belonging to the families Gramineae, Compositae, Convolvulaceae, Cyperaceae, and Fabaceae weeds accounted for 61.48% of the total weed flora surveyed in Tana Beles Sugarcane plantation fields.

Among the dominant weed families in Arjo Didessa sugarcane plantation, four of them (Poaceae, Asteraceae/Compositae, Euphorbiaceae, and Fabaceae) were also recorded as the most important weed families in sugarcane plantations of Coimbatore (India), Louisiana, Mauritius, and China (McIntyre, 1991; Lianming and Chuxiong, 2003). These families are rich in species composition and are outstanding as they contain many weed species [19,20].

Hidalgo et al. (1990) reported that flora diversity is estimated to be high if the average number of species per field were greater than 19. However, in this study, the diversity of flora in each field varied from 19 to 44 (mean= 32) which is high compared to Hidalgo's finding. This might be due to poor weed management, high accumulation of weed seed banks, high rainfall with hot weather conditions, and free fertilizer application. Moreover, Pulschen (1990) described the botanical family to be regarded as highly diversified if it contains more than five species. In this study, 6 families were most diversified and contributed about 121 species which is 71.59% of the total flora. The richest taxa families include Compositae, Convolvulaceae, Cyperaceae, Fabaceae, Poaceae, and Solanaceae which accounted for 113 species which is above half (66.86%) of the whole flora in the plantation site [21,22].

Frequency, abundance, and dominance

In the weed floras recorded, the most frequent species accounting ≥ 10% frequency values were: Rottboellia cochinchinensis (37.14%), Ageratum conyzoides (29.28%), Echinocloa colona (28.86%), Cyperus rotundus (28.57%), Bidens pilosa (26.43%), Corchorus trilocularis (20.71%), Cyperus esculentus (20.71%), Acalypha crenata (19.28%), Aeschynomene aspera (19.28%), Eleusine indica (14.28%), Commelina benghalensis (12.14%), Panicum dichotomiflorum (12.14%), Allium neapolitanum (10.71%), Commelina latifolia (10.71%), Eriocloa fatmensis (10.71%), Cyperus iria (10%), and Digitaria ciliaris (10%) [23,24].

The weed species having greater than 5 abundance values were Cyperus esculentus (20.71), Rottboellia cochinchinensis (15.94), Ageratum conyzoides(13.34), Acalypha crenata (11.5), Cyperus rotundus (10.86), Aeschynomene aspera (10), Bidens pilosa(6.94), Echinocloa colona (6.23) and Physalis minima (5.29) [25].

Moreover, the weed species having a dominance value of > 2.4 plants/m2 were: Cyperus esculentus (11.39), Rottboelliacochinchinensis (8.77) Ageratum conyzoides (7.34), Acalypha crenata (6.33), Cyperus rotundus (5.97), Aeschynomene aspera (5.50), Bidens pilosa (3.82), Echinocloacolona (3.43), Physalis minima (2.91) and Commelina latifolia (2.48) [26].

Importance value index

The number of weed species from a family does not necessarily represent the implication of that family in terms of aggressiveness. For instance, the top five most important weed species in the plantation field that has more than 14 importance value indexes were Cyperus esculentus, Rottboellia cochinchinensis, Ageratum conyzoides, Cyperus rotundus, and Acalypha crenata. Hence, even if the Gramineae family was the most dominant, its entire species except Rottboellia cochinchinensis, others were not important weeds. Correspondingly, Compositae was the second important family in the estate but there are no such an important weed species of this family in their aggressiveness in the estate other than Ageratum conyzoides [27,28].

More to the point, according to their IVI weed species in ascending order were: Commelina latifolia (6.47), Physalis minima (7.12), Echinocloacolona (10.76), Bidens pilosa (11.35), Aeschynomene aspera (13.71), Acalypha crenata (15.37), Cyperus rotundus (15.95), Ageratum conyzoides (18.79), Rottboellia cochinchinensis (22.75) and Cyperus esculentus (25.69) in the plantation site irrespective of soil type, sugarcane crop types and cane cultivars.

Similarity index value of weeds in the plantation site

The similarity index is the similarity of plant species composition among different soil types, crop types, and sugarcane cultivar types of the estate. As described by Taye and Yohans (1998), if the similarity index value is greater than 60%, it is assumed that the two locations, cane crop types or cultivars are similar in species composition and hence the same weed control method can be adopted. However, if the similarity index is below 60%, it is assumed that the two soil types or cane cultivars have different weed communities and different weed control methods can be adopted (Taye, 1991) [29,30].

The similarity indices of weed communities of the present study in different soil types of different sugarcane cultivars in the fields of the plantation ranged between 35.23% and 59.05%. Since similarity indices for the different soil types of different sugarcane cultivars were less than 60% it can be concluded that the soil types of different sugarcane cultivars demonstrated different weed communities and thus, require different management options. Soil classes, types of herbicides used, and management practices adopted in the different fields of the plantation might be the causes of this dissimilarity. The difference in altitude, climate, soil types, and field management practices applied to the different districts could be the cause that affected the distribution, abundance, and dominance of the weed species (Takim and Amodu, 2013) [31,32].

Conclusion

Weed species diversity and quantitative assessment are very important to identify economically important weeds so that weed control strategies could be devised. Based on the present study, a total of 169 weed species belonging to 100 genera within 34 families were identified. The importance of each species was determined by calculating the frequency, abundance, dominance, relative frequency, and importance value index values. The most dominant families according to the frequency, the number of weed species, and flora percentages were Poaceae, Compositae, Cyperaceae, Fabaceae, Convolvulaceae, Solanaceae, Euphorbiaceae, Amaranthaceae, and Malvaceae. Weed species composition, abundance, and distribution varied between fields within the same strata at the plantation site. A large number of weed flora with diverse species dominated the plantation site. Furthermore, the study revealed that the two cane crop stages and the two soil types have different weed communities; hence, different management options could be adopted independently. Therefore, assessment and detection of weed flora need to be done frequently at a certain time interval to see the flora dynamics and the newly introduced weeds in the plantation site.

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Competing Interests

The authors declare that they have no competing interests

Data availability statement

The raw data used to support the findings of this study are available from the corresponding author upon request.

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