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Research paper

A novel approach to phytosociological classification of weeds flora of an agro-ecological system through Cluster, Two Way Cluster and Indicator Species Analyses

Muhammad Iqbal[a], Shujaul Mulk Khan[b,*], Muhammad Azim Khan[c], Zeeshan Ahmad[b], Habib Ahmad[d]

[a] Department of Botany, Hazara University of Mansehra, Pakistan
[b] Department of Plant Sciences, Quaid-i-Azam University, Islamabad, Pakistan
[c] Department of Weed Science, the University of Agriculture, Peshawar, Pakistan
[d] Islamia College University, Peshawar, Pakistan

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ABSTRACT

Weed flora has not been analyzed quite often from its phytosociological classification and ecological point of view due to its deteriorating impacts on economic crops. For the first time weed flora in winter wheat fields of the District Malakand, Pakistan were sampled and quantitatively analyzed to identify indicator weeds and weeds associations' formation, using robust multivariate statistical approaches. It was hypothesized that the variation in an agro-ecological system gives rise to diverse associations of weed species under the influence of edaphic and climatic factors and prevailing farming practices under micro and macro habitat. The quantitative ecological techniques i.e., quadrat along transect method were used to find various phytosociological attribute including Density, Frequency, Cover and Important Value Indices of weeds in the region. 1200 quadrates/releves were established for quantification of weed species in one hundred and twenty randomly selected wheat fields in a region of 26727 ha of wheat growing region. Data was put in MS Excel for analyses in the PCORD Version 5 to find out various weed associations and their specific indicator species. Using Cluster and Two Way Cluster Analyses via Sorenson distance measurements five major clusters/plant associations were established using 1,0 data. These species associations were: (1) *Emix-Vicia-Lathyrus* weed association, (2) *Alysum-Cannabis-Lithospermum* weed association, (3) *Oxalis-Lathyrus-Chenopodium* weed association, (4) *Euphorbia-Cerastium-Capsella-bursa* weed association and (5) *Alopecurus-Mazus-Persicaria* weed association. Association 1 includes 17 fields with a total of 170 releves (17 × 10) in the region. Association 2 includes 30 fields and 300 releves (30 × 10), association 3 has 15 fields and 150 releves (15 × 10), association 4 has 34 fields and 340 releves (34 × 10) and association 5 has 24 fields and 240 releves (24 × 10) in the study area. Various climatic factor, edaphic variables and farming practices associated in each field were also examined for comparisons of influencing factors of weed associations and recognition their respective indicator species. Temperature, soil pH, electrical conductivity, soil structure, soil organic matter, lime contents, preceding crops, use of herbicides, time and quantity of manure were the main factors/ingredients responsible for the variation and formation of different associations. Indicator species analysis gave the indicator weeds of each association under the influence of each determining variable. From findings of this research it is concluded that farming practices and edaphic factor show significant effects on recognition of Indicator species, distribution of weed flora and formation of weed associations/communities in the region. Understanding these phenomena could further be used for weeds management purposes under the micro climatic, edaphic and local farming practice regimes. Though the weeds are considered as unwanted plants, nevertheless some of the economically important and rarely distributed weeds also need proper conservation management.

* Corresponding author.
E-mail addresses: smulkkhan@gmail.com, smkhan@qau.edu.pk (S.M. Khan).

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1. Introduction

Weed flora is an integral part of the entire agro-ecological system of a region (Dickinson and Murphy, 2007; Khan et al., 2007; Leuschner and van der Maarel, 2005; Trudgill, 2007; Waring, 1989) though it is considered as a threat to crops from economic point of view (Munyuli, 2013). Such plants cohort increases floral diversity and provide environmental heterogeneity (Adler et al., 2001; Fridley, 2001). Weed species and associations support the crop performance by providing food plus shelter to beneficial insects, birds and hence, enhance services of an ecosystem in the form of pollination, soil erosion, leaching of Nitrogen and pest control (Carlesi et al., 2013; Donald, 2004; Isbell et al., 2011; Kohler et al., 2011; Marshall et al., 2003; Russell, 1989). Biological conservation and management practices could therefore, be applied in the agro-ecosystems to protect important phyto-diversity and indicator species, in such habitat (Khan, 2012; Kent, 2011; Mitsch et al., 2001; Rauscher, 1999). The science of Phytosociology aims to describe, recognize and quantify different plant associations under the influence of various biotic and abiotic factors (Elmore et al., 2000; Garzón et al., 2008; Kent, 2011; Khan et al., 2016; Nagase and Dunnett, 2012). Twenty first century has introduced computing techniques in every field of science including plant science (Drake et al., 2006; Legendre et al., 2005; Podani, 2006). In this context multivariate statistical techniques could be applied in a better way to understand various aspects of agro-ecological diversity (Hair et al., 2010; Hill and Gauch, 1980; Izenman, 2008).

Classification of weeds into associations in specific microhabitats provide base for vegetation and environmental dynamics (Brohman et al., 2005). Each species has specific microclimatic requirements to establish itself successfully in a particular sort of habitat (Cavieres et al., 2007; Kotzen, 2003; Suggitt et al., 2011). Plant association formation is the most peculiar characteristics of vegetation (Clements, 1916; Kramer, 2012) and weeds flora is one of the integral part of it (Anderson et al., 1998; Gaba et al., 2010; Watson and Riha, 2010). Weeds flora is important part of natural vegetation and compete for resources to establish themselves in the habitats of crops where they occur (Ahmad et al., 2016b; Altieri, 2002; Baker, 1965). Certain weed species are important from conservation point of view. Habitat variability affects weeds diversity, distribution and association formation (Iqbal et al., 2015; Marshall et al., 2003; Roschewitz et al., 2005). Understanding of which may help for their control as well as conservation where necessary.

Type of ecological associations can be distinct if established on the bases of Indicator values. Indicator values are the parameters which designate the predictable richness of each species regarding various environmental ingredients (Cáceres and Legendre, 2009; Dufrene and Legendre, 1997; Reed et al., 2008; Ter Braak and Barendregt, 1986). One of the major focus in the field of ecology is the identification of indicators or characteristics species (Abbas et al., 2016; Carignan and Villard, 2002; Dauber et al., 2003; Kremen et al., 1993). It usually reference one or more indicator species for each type of a habitat. Indicator species are among the most sensitive species of a habitat which act as base line to monitor the ecosystem. In addition, classification of the species into association makes it further easier to manage diverse sampled ecological combinations. Such assemblage may be eurytopic and stenotopic (Kremen et al., 1993; Noss, 1990; Shah et al., 2015). Classification, distribution and recognition of indicator species is also affected by various environmental variables like soil conditions, climate and prevailing farming practices (Ahmad et al., 2016a; Khan et al., 2013). Plant associations formation is based on the combination of these factor and phytosociological attributes of the species (Cook and Kairiukstis, 2013). There has been a lot of research going on related to the formation of plant communities in the natural ecosystem. Nevertheless little efforts can be seen to use these techniques for elaboration of weeds in agri-environment.

On the other hand wheat accounts 19% of the total production among major cereal crops. It provides 55% of the carbohydrates consumed by humans globally (Gopinath et al., 2008; Oerke and Dehne, 2004). Approximately 1/3 of the total world population depends on wheat crop for protein and energy requirements. It provides 72% of calories and protein in average diet (Heyne et al., 1987; Khan et al., 2003). The total production of wheat around the world was approximately 724 million tonnes with 10.1 million tonnes in 2016 that was 1.4% worse than previous year due to various environmental factors (FAO, 2016). Whereas, the production of wheat in Pakistan was approximately 25.48 on an area of 8494 million hectares (FAO, 2016). Wheat average yield of 2585 kg ha^{-1} in Pakistan is very low as compared to other wheat producing countries like European Union, China, India and Russian Federation. There are many factors responsible for low yield. One of these major causes is weed infestation. Weed competition decrease wheat yield by 12–35% or 10 billion losses per annum. Though weed species are important from biodiversity conservation point of view

It was hypothesized that climatic and edhapic factors along with farming practices are responsible for the formation of distinct weeds association each with a unique set of indicator species. The main objective of this study was to document, quantify and classify the weed species into different association's types with specific objective to analyze the impact of various environmental factors on the distribution, composition and diversity of weeds in the region in general and indicator species in particular. This study can be utilized as a baseline for further research in the fields of weed ecology general and identification of indicator species of microhabitats in particular.

2. Methodology

2.1. Study area

The study area District Malakand lies in the northern parts of the Khyber Pakhtunkhwa Province of Pakistan and can be located at 34° 35′ North latitude and 71° 57′ East longitude, covering an area of 80,943 km^2 (Iqbal et al., 2015). Agriculture is the primary source of livelihood for the local people in the region. The major economic crops in the area are wheat, sugarcane, tobacco, rice and maize. Various kinds of vegetables and orchard are also grown in the region. Wheat crop is grown in most parts of the in the project area occupies major part of agricultural land. Weeds of wheat were therefore, considered for current research project. Total cultivated area for wheat in the District Malakand is 26727 ha in which total irrigated land is 9715 ha and total non-irrigated land is 17012 ha. In Tehsil Dargai the total area sown with wheat crop in 2013–14 was 10440 ha in which 5465 ha was non-irrigated and 4975 ha was an irrigated land (Statistical Officer Agri Deptt Dargai). Geographic Information System (GIS) tools were used to design map of the study area (Fig. 1).

2.2. Methods

A total of 120 wheat fields were selected randomly at an approximately one kilometer distance from each other having a size of at least one hectare each. Weed species were collected, labeled with tags, dried, poisoned, mounted upon standard herbarium sheets and identified with the help of Flora of Pakistan and other available literatures (Ali and Nasir, 1990; Khan et al., 2013, 2014; Nasir et al., 1972). The specimens were deposited in the Herbarium of Hazara University (HUH) Mansehra, Pakistan. Coordinates i.e., latitude, longitude and elevation were recorded using Geographical Positioning System (GPS) (model Garmin eTrex. HC series, vista HCx) in each sampled field. Quantitative ecological techniques were used to collect weed species data i.e., at each field 10 quadrats of 1 m square were established and density, frequency and cover were measured for each weed species. Importance Value Indices for each weed species were calculated using the formula: