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Comparative assessment of the relative proportion of weed morphology, diversity, and growth under new generation tillage and crop establishment techniques in rice-based cropping systems

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ABSTRACT

A study was conducted in a cropping system mode for rice–wheat (RW) and rice–maize (RM) with crop residue management [without residue (R-) and with residue (R+)] under different tillage and crop establishment (T&CE) techniques. The T&CE techniques comprised conventional tillage (CT) puddled transplanted rice followed by (*fb*) CT wheat/maize (CTTPR-CT), unpuddled transplanted rice *fb* zero-tillage (ZT) wheat/maize (UPTPR-ZT), ZT-transplanted rice *fb* ZT wheat/maize (ZTTPR-ZT), and ZT dry-seeded rice *fb* ZT wheat/maize (ZTDSR-ZT). Results after four years revealed that the relative dominance of weeds followed the sequence of *Echinochloa colona* > *Cyperus iria* > *Caesulia axillaris* > *Alternanthera philoxeroides* > *Ammannia baccifera* in the rainy season, whereas for the winter season, the sequence was *Medicago denticulata* > *Rumex dentatus* > *Phalaris minor* > *Chenopodium murale* > *Cyperus rotundus*, irrespective of the treatments. In the rainy season of 2013, the highest total weed density was recorded in ZTDSR-ZT, which was 43.8%, 56.8%, and 46.7% higher than those in CTTPR-CT, UPTPR-ZT, and ZTTPR-ZT, respectively. However, in 2014, the highest total weed density, which was significant, was recorded in ZTTPR-ZT. The R+ treatment decreased the total narrow-leaved weed density by 7.3% compared to that in the R-treatment in 2014. In the winter season of 2013–14, the sequence of total weed density was ZTTPR-ZT > ZTDSR-ZT > UPTPR-ZT > CTTPR-CT, whereas during 2014–15, the sequence was UPTPR-ZT > ZTTPR-ZT > ZTDSR-ZT > CTTPR-CT. The *P. minor* density in the RW system was 86.7% and 16.2% higher in 2013 and 2014, respectively, than that in the RM system ($P < 0.05$). Narrow-leaved weeds represented > 65% of the total weed density in ZTDSR-ZT during the rainy season, whereas in the winter season, broad-leaved weeds represented > 90% of the total weed density in both years irrespective of the treatments. Shifting from CTTPR-CT to UPTPR-ZT and ZTDSR-ZT systems resulted in significantly higher Shannon, evenness, and richness indices, thus indicating that the reduction in tillage intensity increased the weed diversity. However, the ecological dominance (C) was higher in CTTPR-CT (0.234) than in the remaining T&CE practices. The contribution of narrow-leaved and broad-leaved weeds toward total weed biomass became pronounced in the UPTPR-ZT, ZTDSR-ZT, and ZTTPR-ZT compared to the CTTPR-CT. The intensity of the total weed density was diminished in the ZTTPR-ZT and ZTDSR-ZT during 2014–15 compared to that during 2013–14. The results of the study can contribute to the development of effective weed management strategies under changing tillage regime for higher crop productivity.

1. Introduction

Half of the world's population consumes rice (*Oryza sativa* L.) as a staple food. Rice cultivation in puddled soil with manual transplanting is a common practice in the South Asian countries. Tuong and Bouman (2003) predicted that rice growers in Asia will face irrigation water scarcity in the future. Additionally, puddling operation adversely influences the succeeding non rice crops because of the decaying effects

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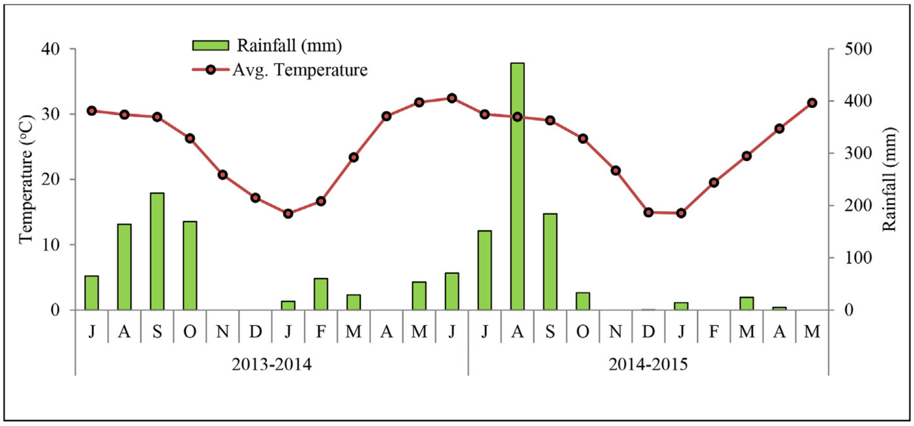

Fig. 1. Weather data during the experiment period.

on soil structure (Timsina and Connor, 2001). Unpuddled transplanted rice (UPTPR), zero-tillage (ZT) transplanted rice (ZTTPR), and ZT dry-seeded rice (ZTDSR) are alternatives to the transplanted puddled rice (TPR) for resolving the edaphic conflict in rice and succeeding crops. Previous studies from Australia, South Asia, and China revealed that dry-seeded rice (DSR) can be successfully grown under conventional tillage (CTDSR) or ZT conditions in place of TPR (Beecher et al., 2006; Gupta et al., 2002; Yan et al., 2010; Chauhan and Opeña, 2012). The ZTTPR, UPTPR, and ZTDSR systems require less labor and fuel compared to the TPR system (Chauhan and Johnson, 2009).

Bhushan et al. (2007) reported a reduction in the yield in UPTPR, ZTTPR, and ZTDSR systems compared to the TPR technique. Weeds pose a great menace in DSR cultivation and make this system vulnerable (Chauhan, 2012; Mahajan et al., 2013). The DSR cultivation is particularly threatened by dominance and diversity of weed flora. Concurrent emergence of rice and weed seedlings, the absence of puddling operation to minimize weed density, and lack of rice seedling size advantage compared to weed seedlings further intensify the weed infestation. Moreover, the land preparation techniques without puddling in DSR and TPR frameworks alter the weed seed dispersal mechanism across the soil depths as well as weed diversity and dominance (Chauhan and Opeña, 2012). The weed flora shift has been well documented in the DSR system. For instance, Timsina et al. (2010) reported a higher weed infestation in CTDSR with perennial species [*Cyperus rotundus* L., *Cynodon dactylon* (L.) Pers., *Paspalum distichum* L.], annual sedges [*Fimbristylis miliacea* (L.) Vahl. and *Cyperus difformis* L.], and annual grass (*Ischaemum rugosum* Salisb.), whereas the infestation of perennial and annual weeds was minimal in the ZTDSR system in contrast to CTDSR. Tuong et al. (2005) and Chauhan and Johnson (2009) stated that DSR cultivation shifts weed flora in favor of annual grasses. Nevertheless, generalized perceptions are difficult to formulate, as the tillage-induced effects are specified in form of location and weed species. Hence, a precise examination is warranted for weed dominance and diversity under new rice establishment techniques (UPTPR, ZTTPR, and ZTDSR).

Changes in soil disturbance pattern because of the modification in crop management practices can also alter the weed dominance and community composition (Nath et al., 2017a). The crop management practices that include crop rotation and residue management significantly influence the weed population dynamics (Ball, 1992). Moreover, variation in the crop rotation/sequences may suppress the germination of some weeds while hastening the emergence of other weeds (Dorado et al., 1999). Rao and Nagamani (2010) recommended that it is obvious to go beyond herbicide-focused weed management for an integrated weed management (IWM) study in India. Hence, in the pursuit of more sustainable weed management approaches, there is a sheer urgency to amalgamate the knowledge of weed ecology and crop management practices.

We hypothesized that alteration in tillage and crop establishment (T&CE) techniques and crop management practices will have a differential impact on the composition of weed flora. Understanding the spectrum of weed diversity and morphological distribution in alternative/new T&CE practices under different cropping systems with or without crop residue is the need of the present time. Hence, a study was undertaken to investigate the effect of T&CE practices in different cropping systems on weed diversity, growth, and community structure.

2. Materials and methods

2.1. Site and soil characteristics

The experiment was initiated during the winter season of 2009 at the Indian Council of Agricultural Research–Research Complex for Eastern Region, Patna, Bihar (25°37′ N, 85°13′ E). The climate of the experimental site is subtropical humid with a minimum temperature of 7–9 °C in January and a maximum temperature of 36–41 °C in June. Relative humidity of 70–90% was experienced throughout the year. The weather parameters during 2013–14 and 2014–15 are presented in Fig. 1. The soil of the experimental field belongs to the order *Inceptisol* under the taxonomical class *Typic Ustochrept* with a silty–clay texture composed of 15.0%, 41%, and 44% of sand, silt, and clay, respectively. The physicochemical properties of the soil at a depth of 0–15 cm included the following: pH 7.11 (a soil-to-water ratio of 1:2), 0.38 dS m^{-1} EC, 0.49% organic carbon, 135.2 kg ha^{-1} available nitrogen (N), 35.2 kg ha^{-1} available phosphorus (P), 239.2 kg ha^{-1} available potassium (K), and 1.44 Mg m^{-3} of bulk density.

2.2. Treatment details

The experiment was initiated in the winter season of 2009. The observations on weed diversity and dominance were recorded in rice–wheat (*Triticum aestivum* L.) (RW) and rice–maize (*Zea mays* L.) (RM) cropping systems during 2013–14 and 2014–15 (at the fourth and fifth years of crop cycle, respectively). The experiment was laid out in split–split plot design with three replications accommodating crop rotation, residue management, and T&CE techniques in the main plot, subplot, and sub-subplot, respectively. The two crop rotations [RW and RM], two crop residue management [without residue (R-) and with residue (R+)], and four T&CE techniques, namely, conventional tillage (CT) transplanted puddled rice followed by (*fb*) CT wheat/maize (CTTPR-CT), UPTPR *fb* ZT wheat/maize (UPTPR-ZT), ZTTPR *fb* ZT wheat/maize (ZTTPR-ZT), and ZTDSR *fb* ZT wheat/maize (ZTDSR-ZT) were undertaken in a fixed plot in each year. The field preparation for different T&CE techniques is depicted in Table 1. The sub-subplot was 10.5 m × 7.5 m in dimension for both years.