

Climate-smart agriculture practices

for reducing weed menace in the rice-wheat system

H S Jat, S K Kakraliya*, M K Gora and P C Sharma

ICAR-Central Soil Salinity Research Institute, Karnal, Haryana 132 001

*Climate-smart agriculture (CSA) practices are an alternative to the conventional system in major agri-food systems of South Asia. These practices have shown a direct role in improving farm productivity, profitability, and soil and environment quality while saving natural resources (soil, water, energy) and delimiting the environmental footprints. Conservation agriculture based practices have already shown the potential in suppressing the major weeds up to some extent in the rice-wheat (RW) cropping system. A study done at farmers' field suggested lower weed problem in CSA-based wheat system by planting wheat early (last week of October) with retention of previous rice crop residue (average 6–8 t/ha) on the soil surface (as mulch) using combo machine (combine harvesting with super SMS followed by Happy Seeder wheat sowing) intervention. Following CSA-based management instead of the conventional approach of residue burn and intensive tillage helped in solving the problem of weed menace and also reduced environmental pollution associated with residue burning. *Phalaris minor*, *Rumex dentatus* and *Cheropodium album* were reduced to a great extent. The CSA-based RW system could be a promising alternative for the weed suppression over conventionally managed RW systems in northwest India.*

Keywords: Crop residue, Sowing time, Weeds, Zero tillage (ZT)

RICE (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) (RW) is the most important agricultural production system occupying an area of 13.5 mha in the Indo-Gangetic Plains (IGP) of South Asia. Although western IGP comprising Punjab, Haryana and western Uttar Pradesh account for 50% of the total area in the RW system of India (~10 mha). Mostly the conventional tillage (intensive tillage based) practices are being followed in the region to achieve high productivity over the years but all at the cost of over-exploitation of resources (i.e. groundwater, soil, energy) and high use of inputs (i.e. irrigation, fertiliser, herbicides and pesticides). In a few years, the productivity and sustainability of the RW system will be threatened because of the inefficiency of current production practices, and shortage of resources. Furthermore, continued cultivation of the same cropping system (i.e.

rice-wheat system) over the last six decades allowed certain weed species like *Phalaris minor* to adapt, increase their establishment, seed bank and profusion. Such weeds adversely affect resource use efficiency (light, water and nutrients) and crop productivity. On a global scale, the yield losses from weeds amount to 40%, which is more than those coming from collective effects of diseases, insects and pests. In the western IGP, weed infestation negatively influences wheat production, particularly under conventional wheat management systems. Weed infestation could decrease wheat yield by 10–35% in most cases or even 100% depending on the intensity of infestation in the region. *P. minor* is the most problematic weed in wheat, gaining resistance against numerous common herbicides after every 2–3 years. Besides adverse impacts of herbicide on the environment

and its high cost, herbicide resistance is emerging in large-scale areas in different crops and cropping systems, making chemical control less reliable. Therefore, weed management is becoming increasingly important for future cropping systems to sustain the productivity of RW systems. Under conventional agriculture, tillage practices change the weed seed distribution both vertically and horizontally, leading to deeper seed banks in the soil, thus affecting seed viability, emergence and seedlings survival, and modifying weed species abundance and composition over a longer period of time. Therefore, CSA-based management practices involve water-smart (direct seeded rice, laser land leveling, tensiometer and weather forecast based irrigation), nutrient smart (site-specific nutrient management through nutrient expert tools, green seeker, slow-release nitrogen

fertiliser and right placement of fertilisers), carbon smart (residue retention and incorporation), weather smart (index-based crop insurance, weather forecast), energy-smart (laser land leveling, direct seeded rice and zero tillage) and knowledge smart (information and communication technology) practices show higher productivity, profitability, and resource use efficiencies are also capable of reducing GHGs and escaping the weed problem in RW system. ZT is the most important key technology that facilitates early planting by reducing the turnaround period because of direct drilling in ZT conditions. Early wheat planting has demonstrated a positive impact on wheat yield by reducing weed population and also mitigating the negative effect of terminal heat stress.

In the present scenario, rice straw has very little or no economic use in western IGP and mostly remains unutilized. It is difficult to initiate tillage and seeding operations in the field having loose and unevenly heaped residue after the combined harvesting of the rice crop and there is also limited time for the planting of subsequent wheat crop, therefore open-field residue burning is a preferable practice in western IGP. In Punjab, 20 million tonnes (54% of the total) of rice and

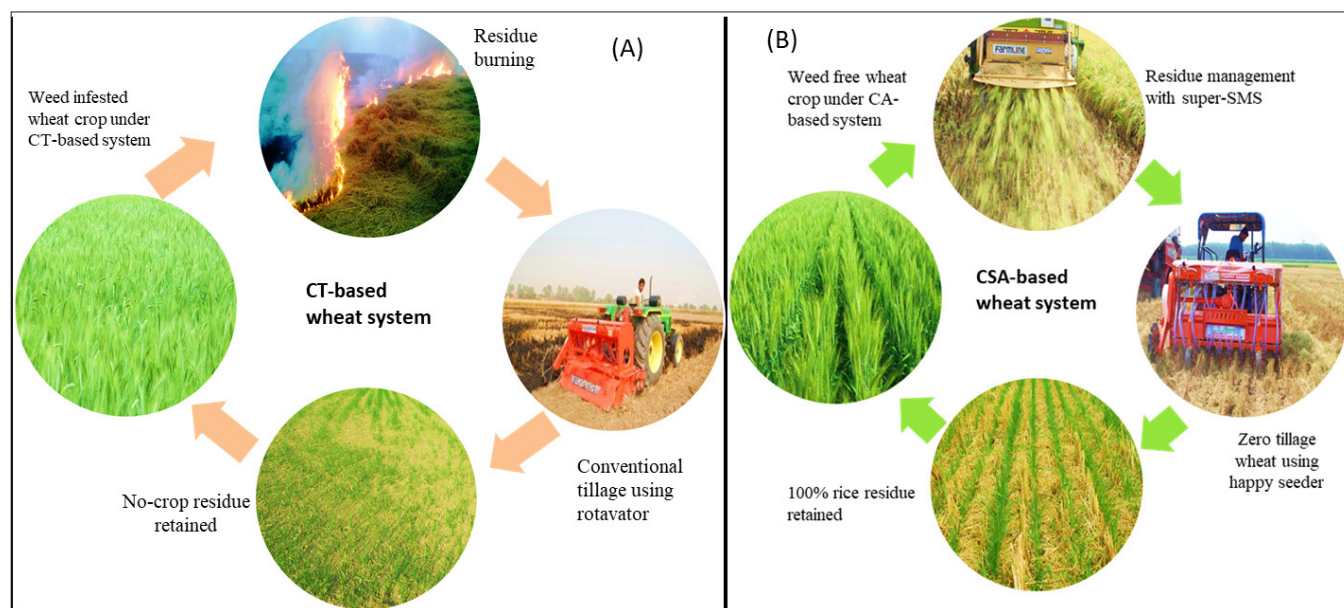
wheat residues are being burned *in situ* annually, leading to a loss of about 8 million tonnes of C, and 1×105 tonnes of N, in addition to the loss of S. The recent version of the happy seeder has been recognized as one key technological innovation that was developed and validated under diverse farmer circumstances. Happy seeder initiates a new approach to solve the shortcomings of direct drilling of wheat into heavy rice residue load, as surface mulch in a single operational pass. It also facilitates well-timed planting with higher crop productivity. The ZT wheat system in IGP of India has been found to advance the planting time, thereby decreasing the *P. minor* population in wheat from normal planting of wheat. In IGP, many studies were conducted across the production systems with different ecologies and showed the potential benefits of CSA-based practices. Therefore, a survey on farmer's fields was conducted to observe the effect of different CSA-based crop management practices and planting dates on weed species with a particular emphasis on *P. minor* and crop productivity.

Observation sites and protocols

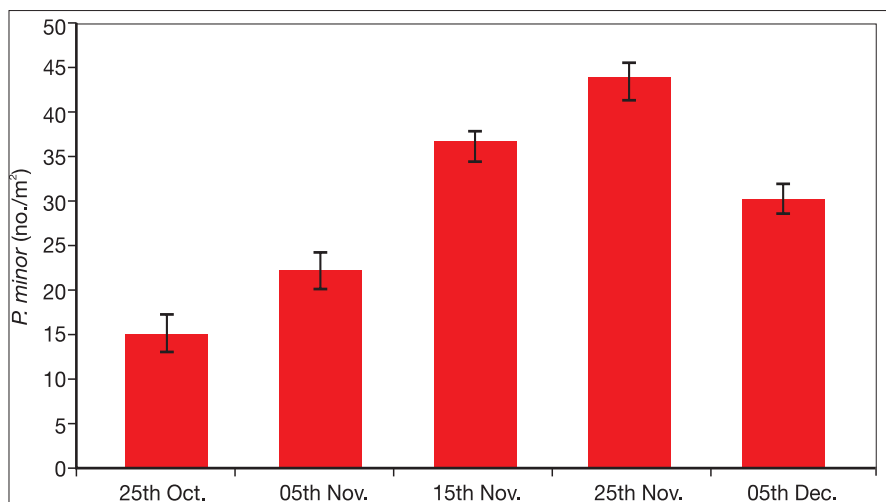
Data collected through a field survey conducted for three consecutive years (between 2018 and 2021) from 12-climate smart villages (5 locations were selected

from each village) in Karnal district of Haryana was used to evaluate the effect of rice residue load on the emergence of *P. minor*, *R. dentatus*, *C. album* and date of sowing of wheat on *P. minor*. The first study included five sowing dates viz. extra early–25 October, early–05th November, medium–15th November, late–25th November and very late–05th December. Also, the samples were collected from five residue levels, viz. 0.0 t/ha (complete burning and CT-seeding), 2–4 t/ha (partial burning and use of rotavator), 4–6 t/ha (removal of loose residue and spatial ZT machine sowing), 6–8 t/ha (spreading of loose residue and happy seeder sowing) and 8–10 t/ha (combining harvesting with super SMS (Straw Management System) and happy seeder sowing).

After three years, it was seen that wheat planting dates significantly reduced the *P. minor* emergence. At 60 days after sowing (DAS), *P. minor* emergence was 65% and 57% (3 years mean) lower in early-planted wheat (October 25) compared to normal (November 15) and delayed-planted (November 25) wheat. Earlier findings also demonstrated successive increase in weed infestations under delayed sowing from early (25 October) to normal (5–15 November) to mid-late (15–30 November) and decrease at late-sowing (December). Indeed, an ideal temperature required for



Different crop management under CT-based (A), and CSA-based wheat rotation (B)

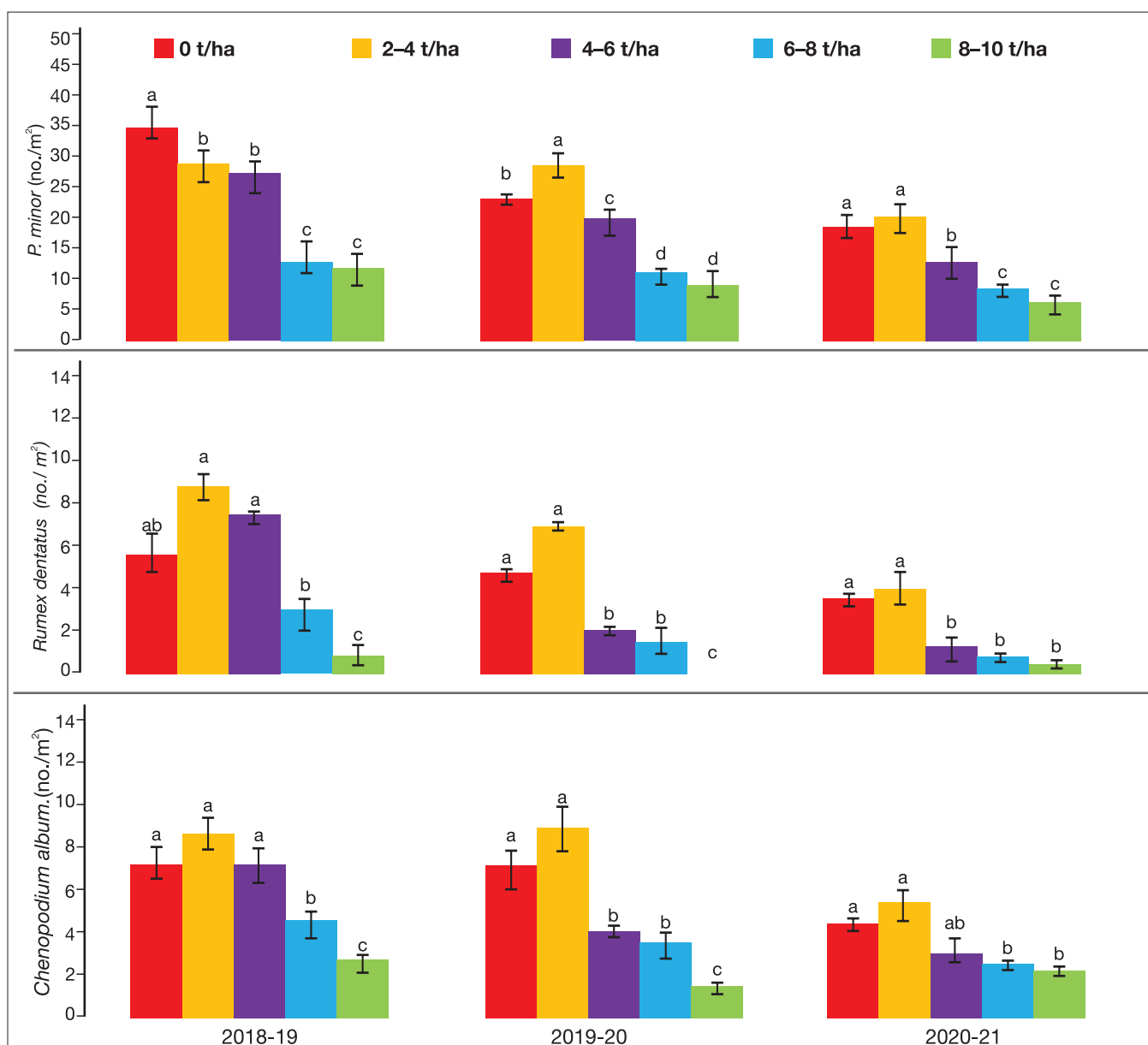


Effect of wheat planting dates and rice residue load on *P. minor* emergence at 60 DAS

temperature was below 11°C which continued till January. Thus, higher (October to the first week of November) and lower temperatures (December–January) hampered the germination of *P. minor*.

Similarly, the amount of residue load on the soil surface influenced the weed emergence dramatically and reduced the emergence of *P. minor* in the range of 16–75% depending on residue mulch load. The emergence of *P. minor* reduced with increasing residue load and ranged from 57–64% at 6–8 t/ha to 69–75% at 8–10 t/ha compared to no mulch plots (farmers' practice) in 3 years. *P. minor* was almost unable to emerge with a residue load of 8 t/ha or more. Decreasing density

the germination of *P. minor* is 17–20°C. In November, the minimum ambient temperature was 16°C, whereas in December the minimum



Phalaris minor, *Rumex dentatus* and *Chenopodium album* density (no./m²) as influenced by different rice residue loads in ZT wheat

of *P. minor* overtime under a CSA-based management system was seen. In ZT, a higher portion of weed seeds present close to the soil surface increased the potential of its germination during the initial years which resulted in the weed seed bank early.

Also, in ZT, weed seeds are more vulnerable to predation and mortality and lose viability risks, leading to unviable seeds and seed bank depletion over time. Thus, the adoption of ZT resulted in seed bank tiredness and reduced the above-ground weed infestation. Retention of crop residue on the soil surface imposes a physical barrier to emerging seeds and restricts the growth of germinated ones by limiting light availability. Crop residue might also suppress weed germination by releasing biochemicals (allelopathy), which tend to affect smaller seeds, in particular. Crop diversification breaks the continuity of weed density and diversity.

Similar to *P. minor*, other weed species like *Chenopodium album* and *Rumex dentatus* also showed a downward trend under ZT wheat with rice residue retention. In three

years, the density of *C. album* and *R. dentatus* was evidently reduced due to all CSA-based practices with crop residue having the utmost effect. In three years, the seed bank of wheat weeds including *P. minor*, *R. dentatus* and *C. album* decreased by 57–64%, 47–79% and 36–54%, respectively, under CSA-based systems (ZT in combination with full retention of rice residue as mulch) compared to farmers' practice or without residue plot.

It has been reported that ZT in combination with residue mulch reduced the weed problem particularly of *P. minor* (the most dominant weed of wheat) over time in ZT wheat than without residue. A reduced population of this weed doesn't mean that the *P. minor* problem will be solved by ZT alone. It also does not mean that farmers will stop using herbicides. Our long-term trials at CSSRI indicated that farmers can skip herbicide once in 3–4 years. There is a constant danger that this weed will constantly evolve resistance to new herbicides and the cross-resistance occurred. Hence, using herbicides alone is not a long term solution for managing resistance. The emergence of a

very heavy population during the early phases of crop cycles can be prevented with ZT.

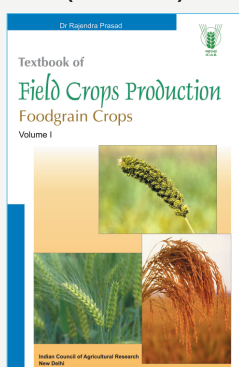
SUMMARY

Weed menace in wheat crops under the RW system can be reduced by early (end of October) wheat planting with retention of full previous rice crop residue on the soil surface as mulch. Farmers in the region generally burn rice residues for ease of land preparation. This approach of keeping residue on the soil surface as mulch (on an average of 6–8 t/ha) not only helps in solving the problem of weeds by ~60% but also reduces environmental pollution associated with residue burning. CSA-based management practices may be an alternative non-chemical weed management practice in place of herbicide use to avoid herbicide resistance, for achieving higher productivity and profitability of wheat.

*Corresponding author's e-mail:
kakraliyask@gmail.com

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TECHNICAL SPECIFICATIONS

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