the remaining nitrogen was top-dressed at panicle initiation. Seeds of Hardinath-5 were sown manually in shallow furrows at 40 kg/ha on 25 June 2024, using 20 cm × 10 cm spacing and a sowing depth of 4-5 cm. Pre-emergence treatments (pendimethalin, pretilachlor and oxadiargyl) were applied within 24 h after sowing, and post-emergence treatments (bispyribac sodium) were applied at 25 days after sowing (DAS). In the combination treatments, 2,4-D was applied as a post-emergence spray at 25 DAS. For pendimethalin + 2,4-D and pretilachlor + 2,4-D, the pre-emergence herbicide was applied within 24 h after sowing and 2,4-D was applied as a follow-up spray at 25 DAS to control broad leaf weeds and sedges that escaped the pre-emergence treatment. For bispyribac sodium + 2,4-D, the two herbicides were tank-mixed and applied together as a single post-emergence spray at 25 DAS. All herbicide sprays were applied with a knapsack sprayer fitted with a flat-fan nozzle. No weed-control measure was used in the weedy-check plots. Weed-free plots were maintained by manual weeding at frequent intervals. One pre-sowing irrigation and six subsequent irrigations were applied as required during the crop season.

2.4 Harvesting and yield determination

The crop was harvested manually with serrated sickles and sun-dried in the field for three days. Grain and straw yields were determined from the net plot. Grain yield was adjusted to a standard moisture content of 14% and expressed in kg/ha using the following equation:

$$\text{Grain yield (kg/ha)} = W_i \times \frac{100-M_i}{100-14} \times \frac{10{,}000}{A}$$

Where, W_i is the initial grain weight (kg), M_i is the initial grain moisture content (%), and A is the net plot area (m^2).

Straw yield was calculated as total biomass yield minus grain yield. To estimate dry straw yield, a 500-g fresh-straw sample was collected from each plot, sun-dried for more than 10 days, weighed, and used to adjust the total straw yield to t/ha. Biological yield was calculated as the sum of grain yield and straw yield using the following equation:

$$\text{Biological yield} = \text{Grain yield} + \text{Straw yield}$$

Harvest index (%) was calculated as follows:

$$\text{HI} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100\%$$

2.5 Observations recorded

2.5.1 Growth and yield measurements

Ten hills were randomly selected and tagged in each plot. Plant height was measured at 15-day intervals from 30 DAS to physiological maturity. Before heading, height was measured from the soil surface to the tip of the highest leaf; after heading, it was measured to the tip of the panicle. The mean of the ten plants represented the plot value.

Two hills were sampled destructively from the designated sampling rows of each plot at 15-day intervals from 30 DAS until harvest. Above-ground biomass, excluding roots, was collected and dried at 70 °C for 72 h in a hot-air oven. Dry matter production was expressed as gm^2. Crop growth rate (CGR) was calculated for each sampling interval following Brown (1984):

$$\text{CGR} = \frac{W_2-W_1}{t_2-t_1} \times \frac{1}{A}$$

Where, W_1 and W_2 are total dry weights at t_1 and t_2 DAS, respectively, and A is the sampled ground area in m^2.