The herbicide 2,4-D (2,4-dichlorophenoxy acetic acid) is a systemic auxin type selective herbicide, belonging to phenoxy acetic group and is recommended to control broadleaf weeds in cereal crops. No doubt, herbicide usage contributes a gainful increment in crop production by way of controlling the weeds and promoting the crop growth and development. However, once a herbicide finds its place in living plant tissue, it may trigger various biochemical changes and alter the metabolism of a plant. Simultaneously, plant may resist the herbicide action by altering the structure and activity of herbicide and converting it into another metabolite. Depending upon these activities, the growth and development of crop plant may be affected. Some authors have reported the effect of 2,4-D on various biochemical processes including photosynthesis, chlorophyll content and sugar content. Chlorophyll is an extremely important biomolecule, critical in photosynthesis, which allows plants to obtain energy from light. Sugars are the ultimate product of photosynthesis in which chlorophyll molecules play an important role. The rate of CO₂ assimilation per unit time is determined by quantity of chlorophyll molecules and this assimilation rate of CO₂ directly governs the total sugar content in leaves. The effect of herbicide on chlorophyll content will directly reflect its effect on photosynthesis. Keeping this in view, the present study was undertaken to find out the influence of 2,4-D on chlorophyll and sugar content in wheat under mid-hill conditions of Himachal Pradesh.

MATERIALS AND METHODS
Field investigations were conducted at the Research Farm and biochemical analyses were carried out in laboratory of Department of Agronomy, forages and grassland management, Himachal Pradesh Krishi Vishvavidyalaya, Palampur. Wheat (variety HPW-155) seeds were sown with recommended packages and practices and 2,4-D were applied at 0.5 kg ha⁻¹, 1.0 kg ha⁻¹ and 2.0 kg ha⁻¹ in wheat crop at 35 days after sowing. The fresh plants were collected at different intervals of time i.e. 0, 15, 30, 45, 60, 90, 120 days after herbicide spray. Total chlorophyll content in fresh wheat plant were estimated by method outlined by Hiscox and Israelstam (1979) and total sugar were estimated in oven dried samples (60°C) by Hedge and Hofreiter method. Wheat grains collected at maturity of crop were oven dried in hot air oven at 60°C and were analysed for sugar content.

RESULTS AND DISCUSSION
The data presented in Table 1 revealed that total chlorophyll content in general decreased up to 30 days then an increase
was observed at 60 and 90 days and thereafter decline was noticed at 120 days after herbicide application. Total chlorophyll content as depicted in Fig.1 showed a decreasing trend in all 2,4-D applied treatments at 30 days after herbicide application and decrease in total chlorophyll content was maximum in 2,4-D 2.0 kg ha\(^{-1}\) (35 DAS). At 30 days after herbicide application significantly lowest chlorophyll content (1.14 mg g\(^{-1}\) fresh weight) in leaves of wheat plant was found in 2,4-D 2.0 kg ha\(^{-1}\) (35 DAS) whereas control being statistically at par with 2,4-D 0.5 kg ha\(^{-1}\) (35 DAS) resulted into highest chlorophyll content (1.69 mg g\(^{-1}\) fresh weight) in wheat plant. Further sampling at 60 days after herbicide application revealed that chlorophyll in leaves increased irrespective of treatments. At 60 days after spray, 2,4-D 0.5 kg ha\(^{-1}\) (35 DAS) and 2,4-D 1.0 kg ha\(^{-1}\) (35 DAS) remaining statistically at par maintained their significant superiority over other treatments. At 90 days after spray the values of total chlorophyll content in leaves varied from maximum (2.69 mg g\(^{-1}\) fresh weight) in 2,4-D 1.0 kg ha\(^{-1}\) (35 DAS) treatment to minimum (2.36 mg g\(^{-1}\) fresh weight) in control. At 120 days after herbicide application, 2,4-D 1.0 kg ha\(^{-1}\) (35 DAS) being statistically at par with 2,4-D 0.5 kg ha\(^{-1}\) (35 DAS) resulted in significantly higher total chlorophyll content i.e. 1.94 mg g\(^{-1}\) fresh weight. Control resulted in significantly lowest (1.52 mg g\(^{-1}\) fresh weight) total chlorophyll content.

The data on total sugar content of treated wheat plant (Fig. 2) showed that at 30 days after spray, total sugars decreased considerably in all the treatments. At this stage a sharp decline in total sugars in all three 2,4-D treatments as compared to control check. At 60 days after herbicide spray, total sugar content increased abruptly irrespective of the treatment but sugar content was less in comparison to zero day of application. Control being statistically at par with 2,4-D 0.5 kg ha\(^{-1}\) (35 DAS) resulted into significantly higher value of total sugar (17.3 mg g\(^{-1}\) dry weight) content in plant at 30 days after herbicide application. Whereas, 2,4-D 2.0 kg ha\(^{-1}\) (35 DAS) recorded significantly lowest value (12.4 mg g\(^{-1}\) dry weight) of total sugar in leaves. At 60 days after herbicide application, the values of total sugar content varied from 32.0 mg g\(^{-1}\) dry weight in control check to 38.9 mg g\(^{-1}\) dry weight in 2,4-D 1.0 kg ha\(^{-1}\) (35 DAS) treatment. With advancement of crop growth irrespective of treatments total sugar content in plant decreased both at 90 and 120 days after herbicide application.

The data as evident in Table 1 at both the stages of observation was found to be non-significant. The values of total sugar content in wheat grain varied significantly from 4.2 to 4.7 per cent. 2,4-D 1.0 kg ha\(^{-1}\) (35 DAS) being statistically at par with 2,4-D 2.0 kg ha\(^{-1}\) (35 DAS) showed significantly higher value of total sugar content. It was followed by 2,4-D 0.5 kg ha\(^{-1}\) (35 DAS). Significantly lowest value of total sugar content (4.2%) was recorded in control check. Total chlorophyll content in wheat leaves at 30 days after herbicide application decreased in all 2,4-D treatments as compared to control check. The initial sudden decrease in total chlorophyll content in 2,4-D treated plants might be due to the loss of chlorophyll by disorganization of chloroplast\(^6\). But further increase in chlorophyll content in 2,4-D treated plants at 60 and 90 days after herbicide application may be due to recovery of plants from initial toxic effects and reduced crop weed competition. These factors may have attributed to increase in photosynthetic efficiency of plants.

Data on total sugar content revealed that in all three treatments of 2,4-D, lowest value of sugar content was observed in 2,4-D 2.0 kg ha\(^{-1}\) (35 DAS). The lower values of sugar content in 2,4-D 2.0 kg ha\(^{-1}\) suggests that at higher doses, herbicide after penetration into leaf cell wall bound to plastid, accumulates there\(^4\) and resulted in interruption of carbohydrate biosynthesis in leaves\(^8\). Total sugar content (mg g\(^{-1}\) dry weight) of treated wheat plants clearly indicated the direct relationship of chlorophyll content with sugar content. 2,4-D treatments significantly decreased total sugar in leaves at 30 days after herbicide application (Table 1). At further sampling i.e. at 60 days after herbicide application, higher per cent increase in total sugar content in wheat leaves was observed in all herbicide applied treatments over control check. Presumably, 2,4-D caused stomata closure\(^5\) leading to reduction in chlorophyll contents which resulted in the accumulation of low sugar content in wheat leaves that too up to 30 days after its application. However at further development stages, crop recovery and reduced crop weed competition might have increased the photosynthetic efficiency of plants and in turn led to higher sugar content in wheat plants. Whereas, low chlorophyll contents in control conditions directly reflects its effects on total sugar contents. Hence, it can be hypothesized that sugar content in leaves is also a function of total chlorophyll content in leaves.

Nearly 90-95 per cent of carbohydrate supply to grain is derived from CO\(_2\) fixation after anthesis. The trend of increased total sugar content in wheat grain might be due to increase in value
of total sugar (Table 1) due to their translocation to wheat grains. Further, it can also be inferred that effect of 2,4-D on reduction of photosynthesis due to closer of stomata and carbohydrate metabolism were temporary and recovered with the passage of time. However, the present findings are not sufficient to explain the possible reasons about the recovery of wheat crop after initial toxicity which ultimately led to increase in sugar content in grains.

### REFERENCES

Fig. 1. Effect of different treatments on total chlorophyll content in wheat leaves at different stages of observations.

Fig. 2. Effect of different treatments on total sugar content in wheat leaves at different stages of observations.