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Optimum time span for distinguishing little canary grass (*Phalaris minor*) from wheat (*Triticum aestivum*) crop based on their spectral reflectance characteristics

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ABSTRACT

The study was carried out at Ludhiana during 2006–08 to establish the optimum time span for distinguishing little canary grass (*Phalaris minor* Retz.) from wheat (*Triticum aestivum* L. emend. Feori & Paol.) crop based on their spectral signatures. The experiment was laid out in randomized block design with 6 replications and consisting of 12 treatments comprising 0, 10, 15, 25, 50, 75, 100, 125, 150, 200, 250 plants/m^2 and a pure *P. minor* plot (T_{max}). Results revealed that irrespective of wheat and weed, the per cent red reflectance values decreased as growth period progressed up to 95 days after sowing and increased sharply thereafter due to increased chlorophyll content. Maximum infrared reflectance value was observed at 95 days after sowing. The highest value of infrared reflectance of 25.20 to 66.49% in 2006–07 and 27.93 to 66.24% in 2007–08 was recorded under pure wheat and the lowest, 18.96 to 54.24% in 2006–07 and 18.17 to 55.46% in 2007–08 in pure *P. minor.* However, infrared reflectance values declined after 95 days after sowing up to harvesting due to onset of senescence. The highest radiance ratio and normalized difference in vegetation index values were recorded under pure wheat treatment and minimum under pure weed plots due to dark green colour and better vigour of wheat as compared to *P. minor.* It was observed that by using radiance ratio and normalized difference vegetation index (NDVI), pure wheat can be distinguished from pure populations of *P. minor* after 34 days after sowing and at different levels of weed populations can be discriminated amongst themselves from 68 days after sowing up to 107 days after sowing.

Key words: Discrimination, Little seed canary grass, *Phalaris minor*, Remote sensing, Special signatures, *Triticum aestivum*, Wheat

Wheat (*Triticum aestivum* L. emend. Fiori & Paol.) is an important and widely cultivated cereal crop in the world. In Punjab it is cultivated over an area of 3.47 million ha with a total production of 14.5 million tonnes and an average yield of 4.2 tonnes/ha. Major detriments to higher productivity of wheat are stiff competition from weeds, multiple nutrient deficiencies, insect-pests and incidence of diseases. Uncontrolled weeds can reduce wheat yield to 20–57% (Singh *et al*. 1997). Among different weed species, the infestation by little seed canary grass (*Phalaris minor* Retz.) is rampant and it divests the crop of vital nutrients and lowers the crop yield by 30–50% (Pandey and Singh 1997). Moreover, in the initial stages of growth seedlings of wheat and canary grass cannot be discriminated through visual observation being similar in morphological features. In Punjab about 80–85% of area under wheat is treated with herbicides, as chemical method of weed control has become very popular amongst farmers being very effective and economical. The continuous and indiscriminate use of same herbicide year after year has lead to the development of resistant biotypes of *P. minor* (Malik and Singh 1995) which necessitates need-based use of herbicides. In order to achieve this if major weeds like *P. minor* are identified through spectral measurements, timely and rational weed control measures can be followed, the estimates of loss will be more reliable, accurate and timely forecast of production will enable the Government to plan its agricultural economy with greater degree of reliability. Also decision models can be developed and used for spatially variable herbicide application in precision agriculture. Since reflectance of crops, weeds and soils differ in the visual and near infrared wavelengths, there is potential for using reflection measurements at different wavelengths to distinguish between them. When solar radiation interacts with matter, it may be reflected, transmitted or absorbed. The spectral reflectance of crop canopies is determined by leaf spectral properties, leaf area index (LAI), canopy geometry, background (soil or residue) reflectance, illumination and view angles; and atmospheric transmittance (Bauer 1985).

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When vegetation density is low, background reflectance significantly influences the canopy reflectance. When vegetation density is high, leaves are the primary scattering elements and the background contributes little to overall canopy reflectance.

The spectral properties of leaves are determined by the concentration of chlorophyll and other pigments in the visible (400–700nm) wavelength region, by mesophyll structure in the near infrared (700–1 200nm) region and by amount of water in the middle infrared (1200–2 400nm) region. As leaves expand, mature and senesce, physiological and morphological changes occur that affect their spectral properties. The temporal variation of spectral parameters, ie infrared : red reflectance ratio or radiance ratio and normalized difference vegetation index during the life-cycle of crop represent the growth and development of the crop. With this background, a study was conducted to study the spectral characteristics of little seed canary grass and wheat and to establish the optimum time span for distinguishing little seed canary grass from wheat based on their spectral reflectance characteristics.

MATERIALS AND METHODS

Field experiments were conducted at Punjab Agricultural University, Ludhiana (30°56’N latitude, 75°52’E longitude and 247 m altitude) during winter seasons of 2006–07 and 2007–08. The soil was normal in reaction (*p*H 7.52) and electrical conductivity (0.16dS/m), was low in organic carbon (0.34%) and available nitrogen (229.1kg/ha) and medium in available phosphorus (19.05 kg/ha) and potassium (205.35 kg/ha).

To establish the critical population levels of primary weed specie in wheat, i e *P. minor* and to establish its optimum time span for distinguishing it from wheat, different plant populations of *P. minor*, viz 0, 10, 15, 25, 50, 75, 100, 125, 150, 200, 250 plants/m^2 were maintained in wheat crop and a pure *P. minor* plot was also kept (T_{max}).

‘PBW 343’ wheat was sown on 15, 16 November 2006 and 14, 15 November 2007 with *kera* method using 100 kg seed/ha after treatment with 4 ml chlorpyriphos/kg seed. The gross plot size was 2 m × 2 m and net plot size was 1.8 m × 1.8 m. The experiment was laid out in randomized block design with 6 replications. An amount of 125 kg N, 60 kg P_2O_5 and 30 kg K_2O/ha was applied through urea, di-ammonium phosphate and muriate of potash, respectively. Half the dose of nitrogen and whole of phosphorus and potassium were applied at the time of sowing by broadcast method, while the remaining N was top-dressed after first irrigation. First irrigation to wheat was applied 21 days after sowing and subsequent irrigations were given as per the crop requirements.

The field was charged with *P. minor* seed according to the requirement of different weed population treatments. Under T_{max}, only *P. minor* seed was sown and in T_0 (pure wheat crop) no weed seed was added. The weed population (plants/ m^2) was manually counted at 15 days after sowing and thinning was done thereafter for maintaining different levels of weed population required under different treatments in the experiment.

Spectral reflectance in 2 wave bands, ie Red (625–689 nm) and Infrared (760–897 nm) was recorded at fortnightly interval with the help of hand held ground truth spectro-radiometer and remote sensing parameters were calculated as under:

To determine the spectral signature characteristics of *P. minor*, observations were taken with hand held ground truth spectro-radiometer. Periodic observations on radiometric reflectance in 2 wavebands, i e (600–700nm) and (720–900nm) were recorded at fortnightly interval throughout the crop growth cycle and red reflectance (%) and infrared reflectance (%) were calculated.

Radiance ratio (RR) and normalized difference vegetation index (NDVI) were derived from red and infrared band reflectance by the following formulae:

RR = infrared reflectance (IR)/ red reflectance (R)

NDVI = (IR–R)/ (IR+R)

RESULTS AND DISCUSSION

Red reflectance

Red reflectance (%) data recorded during winter *(rabi)* season of 2006–07 and 2007–08 are presented in Fig 1.

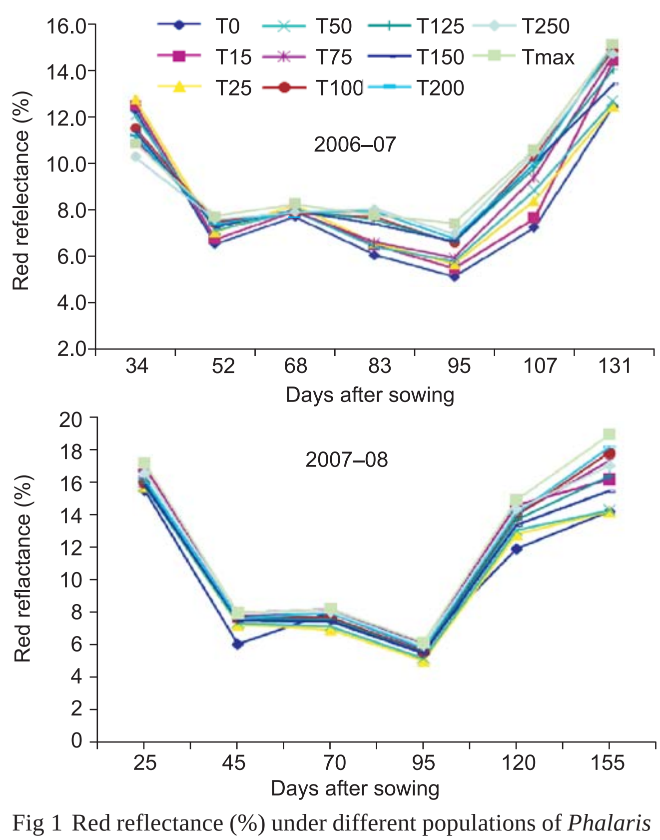

Fig 1 Red reflectance (%) under different populations of *Phalaris minor* during 2006–07 and 2007–08

Irrespective of wheat and weeds, red reflectance value decreased as growth period progressed up to 95 days after sowing and increased thereafter. This may be due to increasing chlorophyll content after 25 days after sowing and absorption of red wavelength by chlorophyll. Similar trend was recorded during 2007–08 where per cent red reflectance value decreased with advancement in crop age up to 95 days after sowing. Among all the treatments, T_{max} (pure *P. minor* weed plot) had the highest red reflectance (15.09 and 18.87%) and T_0 (pure wheat plot) had a lowest value of 5.10 and 6.01% during 2006–07 and 2007–08, respectively. This difference in red reflectance percentage between the pure wheat crop and pure weed plot may be due to higher chlorophyll index and higher leaf area index of the wheat crop as compared to chlorophyll index and leaf area index (LAI) recorded in pure weed plot. Wanjura and Hatfield (1987) also reported that the reflectance and transmittance of visible light by a plant canopy decreased as the LAI increased; meaning a greater portion of visible light was absorbed by the plant canopy.

Infrared reflectance

For near infrared radiation, increase in leaf area index increased the canopy reflectance but relative changes in absorption and transmittance were inconsistent between crop species. In general infrared reflectance values increased under all the treatments with advancement in the growth of crop (Fig 2). Maximum infrared reflectance (%) values ranging from 54.24 to 66.50% during 2006–07 and 45.40–66.13% during 2007–08 were observed at 95 days after sowing in all the treatments during both the years. The highest value of infrared reflectance was recorded under T_0 (pure wheat plot), which ranged from 25.20 to 66.50% (2006–07) and 27.93 to 66.13% (2007–08) and T_{max} recorded minimum infrared reflectance which ranged from 18.96 to 54.24% (2006–07) and 18.17 to 45.40% (2007–08). Higher infrared reflectance recorded in crop may be due to higher dry matter, leaf area index and better vigour of the crop. Chang *et al*. (2004) also reported much greater reflectance in weed-free areas than the weed-infested areas. However, infrared reflectance values declined after 95 days after sowing up to harvesting probably due to the onset of senescence. Similar results were reported by Chang *et al.* (2005).

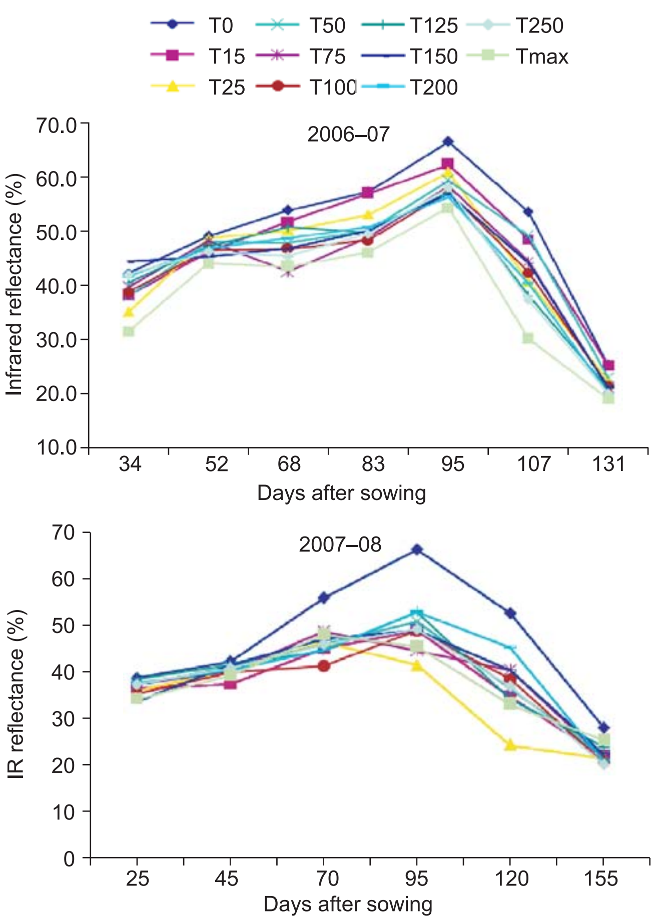

Fig 2 IR reflectance (%) under different populations of *Phalaris minor* during 2006–07 and 2007–08

The high reflectance at the near infrared wavelengths is due to the internal cellular structure of the leaf. As radiation of near infrared wavelengths enters the leaf's mesophyll layer, multiple reflections and refractions occur inside the hydrated plant cells and the air pockets that separate them. Very little of this near infrared energy is absorbed by plant material. Chang *et al*. (2004) reported reflectance rankings in the near infrared range when treatments were consistent between years and from lowest to highest reflectance were, soil<weed free< weed infested areas. Increased reflectance from weed infested areas was most likely due to increased biomass and canopy cover. Feyaerts *et al.* (1998) developed a sensor based on reflectance in visible and NIR spectra, which can detect weeds in corn (*Zea mays* L.) and sugarbeet (*Beta vulgaris* L.) with a success rate of 80%.

Radiance ratio

Radiance ratio (RR) values increased in the early stages of crop growth with increasing green biomass, reached a maximum at maximum crop canopy cover and after that decreased as the leaves senesce (Fig 3). The highest radiance ratio values were obtained at 95 days after sowing in almost all the treatments. The differences in radiance ratio between pure wheat and pure *P. minor* are mainly due to darkgreen colour, more leaf area index and biomass of wheat crop compared to pure *P. minor*. The data on radiance ratio showed that population level of 15, 25, 50, 75,100, 125 and 150 plants of *P. minor* cannot be distinguished from each other in their radiance ratio at earlier stage of 34 days after sowing but higher population levels beyond this including pure *P. minor* (T_{max}) can be discriminated from pure wheat crop at much earlier stage, i e 34 days after sowing during 2006–07. At 52 days after sowing, all the population levels showed different radiance ratio from pure wheat crop but it is difficult to

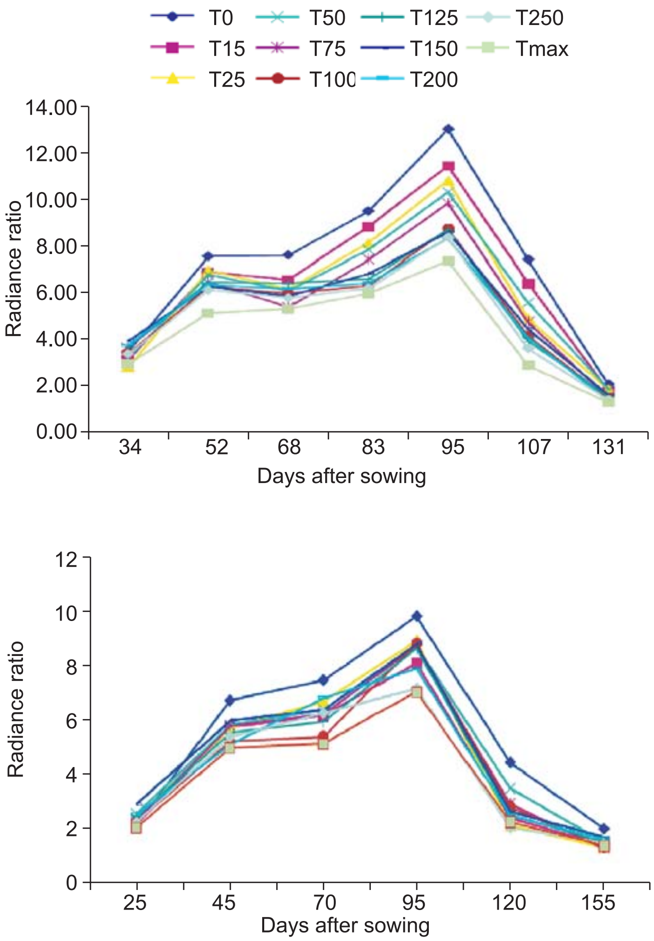

Fig 3 Radiance ratio under varying populations of *Phalaris minor* during 2006–07 and 2007–08

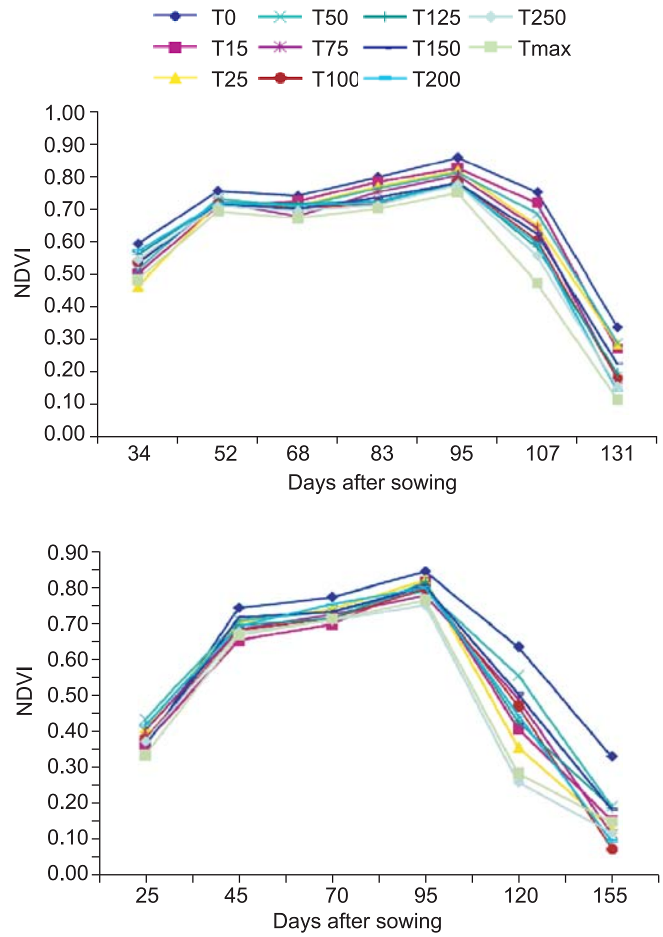

Fig 4 NDVI under varying populations of *Phalaris minor* during 2006–07 and 2007–08

differentiate amongst various *P. minor* treatments. Almost all the levels of plant population can be discriminated amongst themselves after 68 days after sowing and remain distinguished up to 107 days after sowing. The pure wheat plot can be distinguished from different weed population treatments much earlier, i e 34 days after sowing and remains different from rest of the treatments up to 107 days after sowing.

During 2007–08, highest radiance ratio was recorded in pure wheat plot and it was distinguished from rest of the treatments at 45 days after sowing and remains different from rest of weed population treatments up to 120 days after sowing. Pure wheat crop was distinguished from various *P. minor* populations (15–250 plants/m^2) at all observational stages throughout the growing season except at 25 days after sowing. Early in the season when soil background is dominant and later in the season when crop is in senescence stage, *P. minor* and wheat crop cannot be distinguished. However, when *P. minor* population is too high, it can be distinguished from pure wheat crop much earlier, i e 25 days after sowing till 120 days of crop growth.

Normalized difference vegetation index

Normalized difference vegetation index (NDVI) is used to highlight the vegetation component in a soil background and normalization also minimizes the effects of illumination and other measurement conditions. This allows a comparison of the same crop across space and over time. Because of the tendency for healthy vegetation to absorb red light and reflect energy in the NIR, vigorous plants will have a high NDVI value. Conversely, as plant health declines, so does the ability to absorb red light and reflect NIR; this scenario results in low NDVI values signifying a decrease in plant vigour (Henry *et al.* 2004). The Fig 4 showed that NDVI increased with advancement in crop age, reaching the maximum at 95 days after sowing and then decreased due to senescence of leaves in all the treatments during both the years. This is because the absorption of energy in the red region begins to decrease and the reflected energy in the infrared region decreases due to cell degeneration and a decrease in leaf area index. The values of NDVI ranged from 0.34 to 0.87 (2006–07) and from 0.33 to 0.84 (2007–08) in pure wheat and from 0.11 to 0.76 and 0.15 to 0.76 in pure weed plot (T_{max}).

Among all the treatments pure wheat crop (T_0) treatment showed the highest NDVI values (0.87 and 0.84 during 2006–07 and 2007–08, respectively). The separation of weed-free crop from different levels of weed was clearly visible in NDVI. Various population levels of *P. minor* can be distinguished from pure wheat crop at 34 days after sowing during 2006–07 and at 45 days after sowing during 2007–08. Early in the season when soil background is dominant and later in the season when crop is in senescence stage, *P. minor* and wheat crop cannot be distinguished. However, pure wheat crop recorded the highest NDVI throughout the crop growth during both the years. The perusal of the radiance ratio (Fig 3) and NDVI (Fig 4) data revealed that both radiance ratio spectral index and NDVI spectral index are good in distinguishing *P. minor* and wheat crop.

Comparison of the linear and quadratic regressions showed that the regressions of radiance ratio and NDVI on plant height, fresh biomass and total dry biomass were improved when the quadratic model was used, but that LAI was linearly correlated with the spectral indices (Mahey *et al*. 1991).

From the above results it is concluded that the highest radiance ratio and NDVI values were recorded under pure wheat treatment and lowest under pure weed plots. This was due to dark green colour and better vigour of the wheat as compared to *P. minor.* Pure wheat can be distinguished from pure populations of *P. minor* by using radiance ratio and NDVI after 34 days after sowing during 2006–07 and 25 days after sowing during 2007–08 but different levels of weed populations can be discriminated amongst themselves from 68 days after sowing up to 107 days after sowing.

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