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Spectral reflectance characteristics to distinguish *Malva neglecta* in wheat (*Triticum aestivum*)

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ABSTRACT

A field experiment was carried out to distinguishing *Malva neglecta* from wheat (*Triticum aestivum* L.) crop based on their spectral reflectance characteristics through remote sensing during *rabi* seasons of 2010-11and 2011-12. The investigation consists of six treatments each having different population levels of *Malva neglecta,* viz. 0, 3, 6, 9, 12 plants/m^2 and a treatment having pure population or solid stand of *Malva neglecta.* The results indicated a decreasing trend in effective tillers, number of grains/ear, 1000-grain weight and grain yield of wheat with increasing population densities of *Malva neglecta* from 3 to 12 plants/m^2. Highest grain yield of wheat (5.75 tonnes/ha) was recorded under pure wheat treatment (solid stand) and lowest grain yield (3.24 tonnes/ha) was recorded in treatment having 12 plants of *Malva neglecta*/m^2. Higher radiance ratio and NDVI values were recorded in pure wheat treatment and minimum in pure weed treatment. It was observed that by using radiance ratio and NDVI, pure wheat can be distinguished from pure populations of *Malva neglecta* after 30 DAS and remain distinguished up to 120 DAS and different levels of weed population can be discriminated amongst themselves from 60 DAS onwards. From the study it was concluded that remote sensing technology can be used for identification of different weed species and their infestations in field crops. Weed prescription maps can be prepared with Geographic Information System (GIS), on the basis of which farmers can be advised to take the preventive control measures.

Key words: Grain yield, *Malva neglecta,* NDVI, Radiance Ratio, Remote Sensing, *Triticum aestivum*

During the cultivation of wheat (*Triticum aestivum* L.) crop a number of constraints are faced by farmers. Amongst which the infestation of weeds is one of the major constrant. Due to congenial conditions like high soil moisture and low temperature severe weed infestation occur. The population pressure of weeds has great impact on grain yield and a reduction of 7.6-44.2% in grain yield of wheat with increase in weed population from 50 to 200 plants/m^2 has been recorded. Among various broad leaved weed species, *Malva neglecta* pose a threat to successful crop management. *Malva neglecta* is a broad leaf weed belonging to family Malvaceae and is commonly known as button weed, common mallow, dwarf mallow or cheese weed. It mainly infests the roadside areas in large patches, but the infestation of *Malva neglecta* in crops like wheat is going to be a major problem these days. *Malva neglecta* can be winter annual or biennial plant and reproduces only from seed. A single plant can bear a large number of small button like fruits in which seeds are enclosed. In the starting stages of growth it remains spreading type but as the growth proceeds it starts achieving vertical height. Even in the less competitive crop varieties height of the weed may go above the crop canopy. There are different methods employed to control weed flora, viz. cultural, physical, chemical and biological. The manual removal of weeds is very expensive and time consuming method. Herbicides not only control the weed but also reduce the cost of cultivation. However, continuous use of herbicides leads to resistance in weeds, shifting weed flora, environmental pollution, residue of herbicides in soil, persistence in crop produce and biomass (Walker *et al.* 2002 and Andrew *et al*. 1998). Besides, efficiency of any chemical control technique depends on method used as well as time of application. Effective weed management revolves around accurate information on type and extent of weed infestations within a given area before the treatments can be formulated. There is need to tackle the weed problem by devising effective and viable management technique. In the crop fields weeds are spatially aggregated not randomly distributed so their intensity of population varies even within a field. Detection of weed population has become prime importance for selective management of weeds without hazards like environmental pollution and residual effect. For site specific application of herbicides, automatic detection and evaluation of weeds are desirable. Modern management of agricultural resources is a complex endeavour that is now benefiting from a convergence of technical advances in information science, geographic positioning capabilities and remote sensing systems. Much of the fundamental research relating spectral properties of

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soil and crops to agronomic and biophysical parameters has been accomplished by ARS researchers working collaboratively with NASA and university scientists in a variety of programs in USA over the past four decades. Many aspects of crop management have already begun to benefit from applications of remote sensing technology. Plant canopy light reflectance measurements have been used to characterize the spectral characteristics of plant species and aerial photography and video-graphy have proven useful for detecting plant species on rangelands. Many rangeland plant species are distinguishable on aerial imagery, when in specific phonological stages (Everitt and Deloach 1990). Leafy spurge produces showy yellow bracts in late May or early June giving the plant a conspicuous appearance so it might be distinguishable on aerial imagery in this phonological stage. Gibson *et al.* (2004) support the idea that remote sensing has potential for weed detection in soybean, particularly when weed management systems do not require differentiation among weed species.

Everitt *et al.* (1992) reported that Drummond and common golden weed can be separated from other plant species and soil at flowering in the fall. Similarly, Shepherd and Lee (2007) supported that in most instances the best opportunity for scrub weed (*Ulex europaeus*) discrimination occurs during flowering periods. In a recent review on detecting weeds in crops by remote sensing, Lamb and Brown (2001) mentioned that spectral differences between weeds, crops and soils should exist, and be detectable by instruments with enough spectral resolution. Estimates of a 40 to 94% reduction in herbicide use may be realized using site-specific technology (Brown and Steckler 1995 and Mortensen *et al.* 1995). In western Canada alone, this technology could result in substantial savings given that producers spend Can $943 million annually on herbicides. In addition to cost savings, site-specific herbicide application offers the ability to reduce effects on non-target plants and contamination of water bodies as a result of runoff and leaching. As growers gain more confidence on its use, additional opportunities will present themselves. The future brings tremendous prospects for integrating the spatially and temporally rich information provided through remotely sensed multi-and hyper-spectral imagery with the capabilities of management oriented crop simulation models. Keeping in view the importance of remote sensing in site-specific weed management, the present study entitled "Spectral reflectance characteristics to distinguish *Malva neglecta* in wheat (*Triticum aestivum* L.) crop" was undertaken to study the spectral characteristics of *Malva neglecta* and wheat and to find out the optimum time span for distinguishing *Malva neglecta* from wheat crop, based on their relative spectral reflectance characteristics.

MATERIALS AND METHODS

The field experiment was conducted at Research Farm of Agronomy Department at Punjab Agricultural University, Ludhiana during *rabi* seasons of 2010-11 and 2011-12. This site is located in Trans-Gangetic agro-climatic zone and represents the Indo-Gangetic alluvial plains (30°56'N latitude, 75°52'E longitude and at an altitude of 247 m msl). Here, climate is characterized as sub-tropical, semi-arid with hot summer (18.9 to 33.8°C) and very cold winters (5.3 to 17.6°C). The soil was sandy loam, low in organic carbon (0.14%) and available nitrogen (172.2 kg/ha) and medium in available phosphorus (12.1 kg/ha) and potassium (144 kg/ha) having neutral soil reaction (7.6). The electrical conductivity of soil was 0.20 dS/m. The experiment consists of different population levels of *Malva neglecta,* viz. 0(T_1); 3(T_2); 6(T_3); 9(T_4); 12(T_5) plants/m^2 and a treatment (T_6) having only *Malva* species or solid stand of *Malva neglecta.* The experiment was laid out in Randomized Complete Block Design with four replications. The wheat cv PBW 550 was sown on 13th November, in 2010 and 16th November, in 2011 using seed rate of 112.5 kg/ha and recommended doses of fertilizers were applied (125 kg N/ha, 50 kg P_2O_5/ha and 30 g K_2O/ha). The sources of NPK was urea, DAP and muriate of potash, respectively. Half of recommended dose of N and whole of phosphorus and potassium were applied at the time of sowing, and remaining half dose of N was applied as top dressing after the first irrigation. The field was seeded with *Malva neglecta* seed according to the requirement of different weed population treatments at the time of wheat sowing. In T_6 treatment, seeds of only *Malva neglecta* were sown while in T_1 no weed seed was seeded (Solid wheat stand) and weed free situation was maintained throughout the season. Gap filling of the weed plants was done to maintain proper weed count/m^2. No Herbicide was used for weed control. 25-30 DAS, the required weed population in respective treatments were maintained manually by thinning where the weed density was higher than required and by gap filling where there was less weed density. All the agronomic parameters were recorded as per the standard procedures. The grain and straw yield was recorded at 15% moisture level.

Pure white films are good reflectors of light so value of reflectance from a white plane were also recorded. With respect to these reflectance values per cent reflectance by crop in the red band (625-689 nm) of spectrum was calculated at different growth stages of the crop as follows:

RR = Reflectance by crop in red band/Reflectance by the white panel ×100

Similarly per cent reflectance by crop in Near Infrared Region (760-897 nm) was calculated with respect to the reflectance from a reference white film as follows:

IR = Infrared Reflectance by crop in NIR/Reflectance by the white panel ×100

Spectral reflectance in two wave bands, i.e. Red (625-689 nm) and Infrared (760-897 nm) was recorded fortnightly with hand held groundtruth spectro-radiometer and remote sensing parameters like Radiance ratio (RR) and Normalized difference vegetation index (NDVI) were calculated as 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

Yield and yield attributes

The yield and yield attributes were significantly influenced by varying weed densities (Table 1). Data on the ear length of the crop in different treatments was recorded at time of harvest of the crop showed that with increase in weed population density per unit area, a significant decrease in the ear length of the crop was observed. Treatment T_1, with no competition between crop and weeds, had the highest ear length (11.95 cm) which was significantly greater than rest of the treatments. Minimum ear length was recorded in treatment T_6 with 12 plants/m^2 of *Malva neglecta*. Decrease in ear length of crop was due to increased competition between weeds and crop for various factors like space, nutrients, moisture, light etc. It was recorded that presence of 3 plants/m^2 of *Malva neglecta* caused 12.7% reduction in ear length and presence of 12 plants/m^2 caused 37.4% reduction in ear length, respectively, relative to the solid stand of wheat crop, i.e. T_1.

Number of grains per ear

The data on number of grains per ear are presented in Table 1 depicted a decrease in number of grains per ear of crop with increased weed population levels and highest number of grains per ear (42.25) was recorded in treatment solid wheat stand (T_1) which was significantly superior to rest of the treatments. The treatment with 12 plants of *Malva neglecta*/m^2 recorded the lowest number of grains per ear. With increase in population levels of *Malva neglecta* from 3 plants/m^2 to 12 plants/m^2, there was a reduction in number of grains per ear up to 6.3-16.7%. This might be due to shading effect as well as severe competition between crop and weed.

1000-grain weight

Data on the 1000-grain weight revealed that increased weed plant population per unit area resulted in decreased 1000-grain weight of the crop. Maximum 1000-grain weight was recorded in weed free treatment (T_1) and it was significantly higher than rest of the treatments. Lowest 1000-grain weight was observed in T_5 treatment (12 plants/m^2) with maximum crop-weed competition. Highest 1000-grain weight of treatment T_1 (pure wheat) was due to relatively bolder grains of crop in this treatment than other treatments and absence of competition between crop and weeds. Increased competition pressure of weeds on crop decreased the boldness of grains which resulted in decreased 1000-grain weight. Treatments T_4 and T_5 resulted in 7.4 and 10.5% reduction in 1000-grain weight, respectively, compared to treatment T_1. Meisner *et al.* (1992) in their experiment on comparing the two wheat production systems reported that the shrinkage of wheat grains due to the competition posed by different weeds species on the wheat crop was responsible for decreased 1000-grain weight which ultimately decreased grain yield.

Table 1 Yield and yield attributes of wheat as influenced by different densities of *Malva neglecta*

Treatment	Ear length (cm)	Grains/ ear	1000-grain weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)
Solid wheat stand (T_1)	11.95	42.25	40.38	5750	6080
3 plants of *Malva neglecta*/m^2 (T_2)	10.43	39.60	39.18	5060	5610
6 plants of *Malva neglecta*/m^2 (T_3)	9.60	38.10	38.10	4710	5020
9 plants of *Malva neglecta*/m^2 (T_4)	8.55	37.20	37.38	4030	4530
12 plants of *Malva neglecta*/m^2 (T_5)	7.48	35.18	36.15	3240	4020
Solid weed stand (T_6)					
SEm±	0.14	0.37	0.21	46	65
LSD (P = 0.05)	0.40	1.04	0.58	139	189

Grain yield

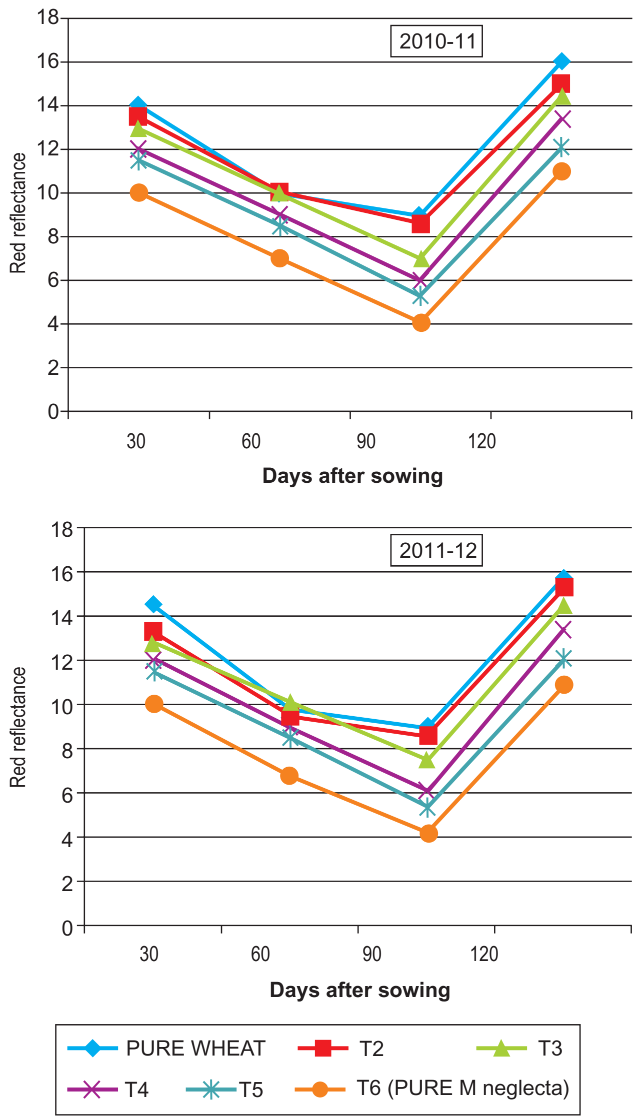
The ultimate objective of all the agronomic studies is to optimize the yield of any crop. Economic yield can be expressed as a function of all the factors contributing towards yield. In case of wheat the yield is a function of final plant population or number of plants at harvest, number of effective tillers, number of filled grains per ear and the weight of individual grain. The data on the grain yield are recorded and presented in Table 1 showed a significant influence of varying densities of weed populations on grain yield of wheat. With the increase in infestation of weed species from 0 to 12 plants/m^2, a decrease in grain yield of wheat was observed. Maximum grain yield (5750 kg/ha) was observed in treatment T_1 with no competition between crop and weeds, which was significantly higher than rest of the treatments. The treatments T_3, T_4, andT_5 (having 6, 9 and 12 plants of *Malva neglecta*/m^2) recorded a reduction of 18.21, 29.9 and 43.7% in grain yield, respectively, compared to weed free treatment, i.e. T_1. At higher weed densities there was greater degree of suppression of wheat plants which resulted in significant reduction in grain yield. Weed species, *Malva neglecta* caused 5-24% reduction in grain yield of crop (with plant density of 3 to 12 plants/m^2). Walia *et al.* (2001) also reported reduction of grain yield to an extent of 30 to 40% under different weed infestations as compared to weed free treatment.

Remote sensing observations

There are several spectral indices which are used in agriculture. Spectral vegetation indices are the most important one and they attempt to measure biomass or vegetative vigour. A vegetation index is a dimensionless, radiometric measure that functions as indicator of relative abundance and activity of green vegetation often including LAI, percentage green cover, chlorophyll content, green biomass and absorbed PAR. A vegetation index should maximize sensitivity to plant biophysical parameters preferably with a linear response in order that sensitivity be available for a wide range of vegetation conditions and to facilitate validation and calibration of the index. The normalized difference vegetation index (NDVI) is used to highlight the vegetation component in a soil background and due to normalization also minimizes the effects of illumination and other measurement conditions. This allows a comparison of the same crop across space and over time. The temporal variation of spectral parameters, i.e. infrared: red reflectance ratio or radiance ratio (RR) and normalized difference vegetation index (NDVI) during the life cycle of crop represent the growth and development of the crop. To study the critical population levels of weed specie in wheat, i.e. *Malva neglecta* and for distinguishing it from wheat based on spectral characteristics, different plant population levels of *Malva neglecta,* i.e. from 3 to 12 plants/m^2 were maintained in wheat crop and the results are presented below:

Red reflectance and infra-red reflectance

The red reflectance (%) data recorded during the experiment is shown in Fig 1 which represents the red reflectance of wheat crop under different population levels of *Malva neglecta* during 2010-11 and 2011-12 respectively. Data revealed that there was decrease in red reflectance of all the treatments irrespective of wheat and weeds from 30 to 90 DAS and thereafter, a sharp increase was observed in all the treatments. This was due to increased chlorophyll index after 30 DAS as red reflectance was reduced by chlorophyll absorption and sharp increase after 90 DAS was due to less absorption of red light by the crop leaves as the crop approaches maturity. Solid weed population treatment (T_6) recorded minimum red reflectance as compared to the rest of treatments. In general IR reflectance values increased in all the treatments with advancement in the crop growth period Fig 2 during 2010-11 and 2011-12 respectively. During the crop season highest value of infrared



T_2, T_3, T_4, T_5 are 3, 6, 9 and 12 plants of *Malva neglecta*/m^2

Fig 1 Red reflectance of wheat crop under different population levels of *Malva neglecta*

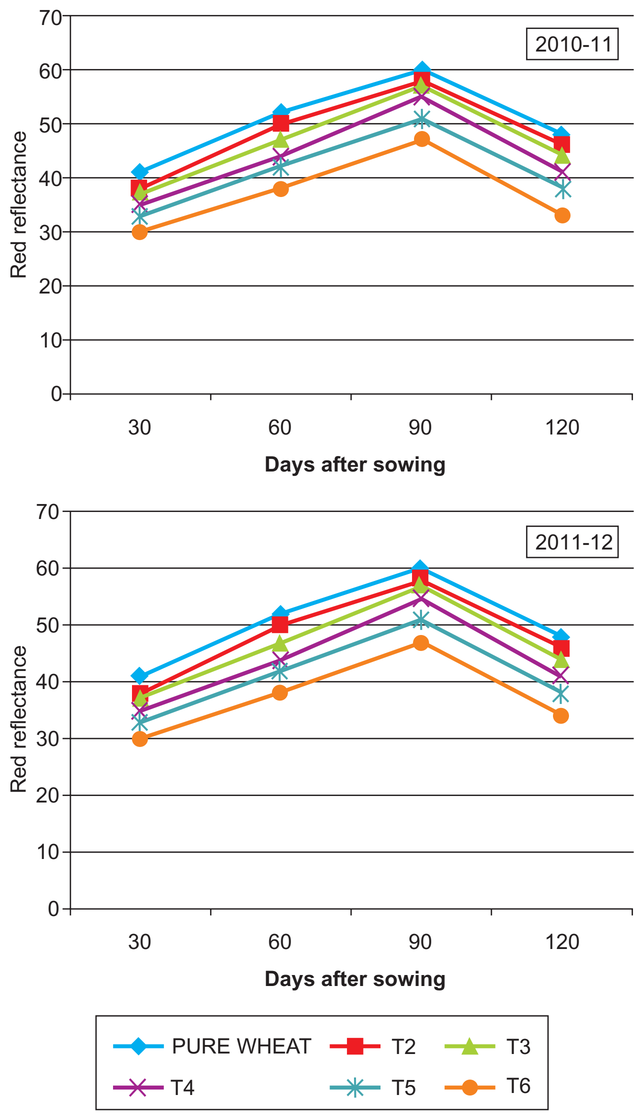


Fig 2 IR reflectance of wheat under different population levels of *Malva neglecta*

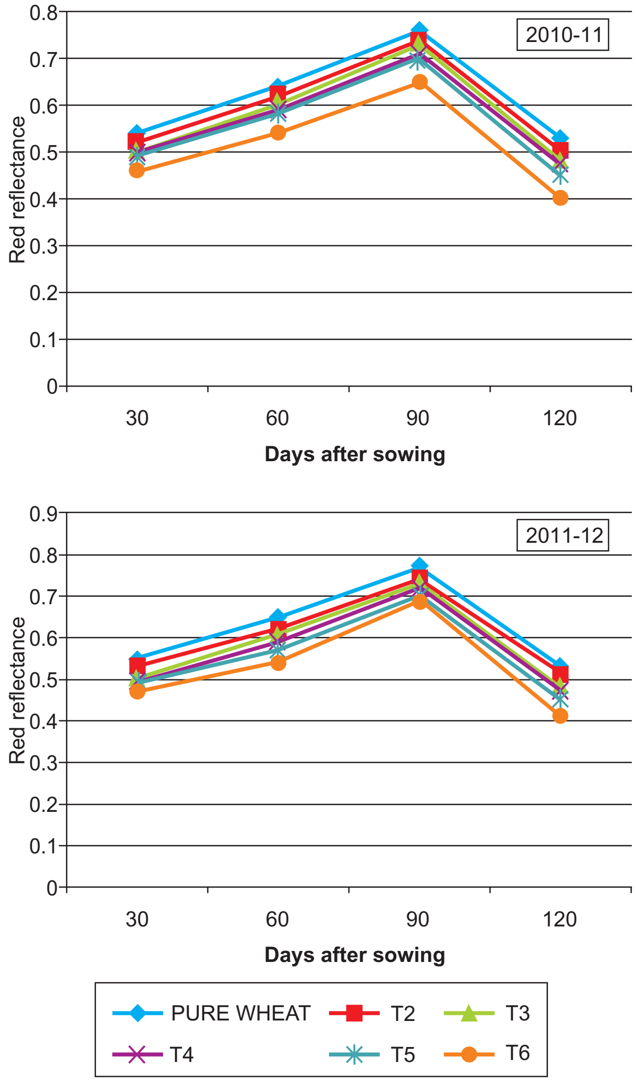


Fig 3 Radiance ratio of wheat crop under varying *Malva neglecta* population intensities

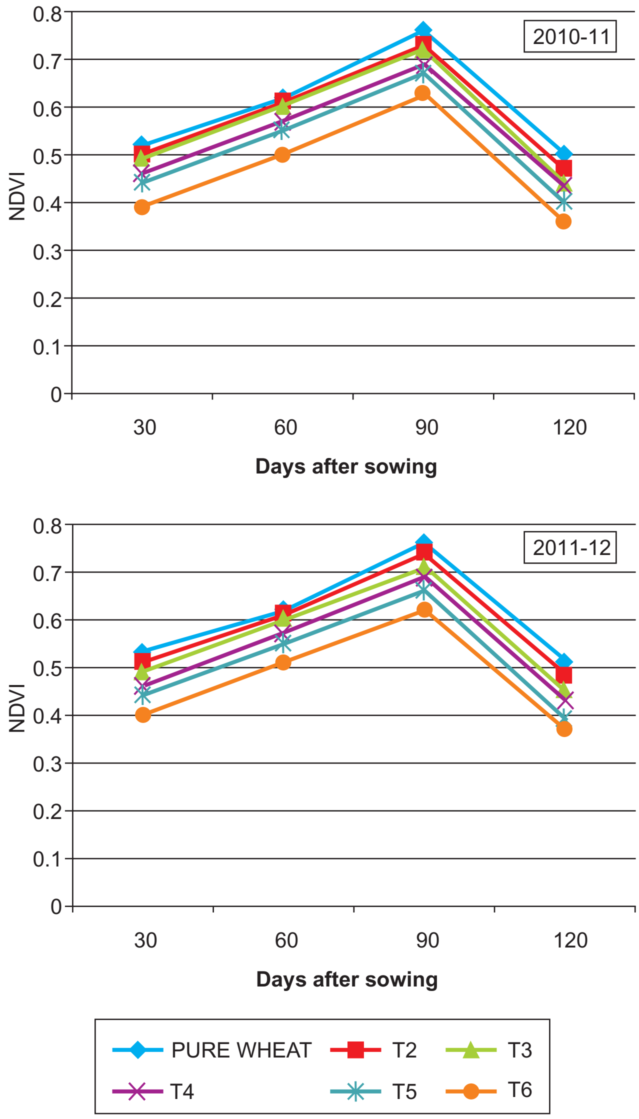


Fig 4 NDVI of wheat crop under different population levels of *Malva neglecta*

reflectance was obtained at 90 DAS in all the treatments. IR reflectance of wheat crop ranged between 30 and 60% under variable population levels of *Malva neglecta*. After 90 DAS, IR reflectance values declined sharply due to advancement of crop towards maturity and more scattering of infra-red light in the mesophyll cells of the leaves which ultimately decreases the reflectance. Similar results were also reported by Chang *et al.* (2005), who reported decreased reflectance in IR region due to wilting. As radiation of NIR wavelengths enters the leaf's mesophyll layer, multiple reflections and refractions occur inside the hydrated plant cells and the air pockets that separate them. In the treatments with *Malva neglecta,* IR of the wheat decreased with increase in weed plant density.

Chang *et al.* (2004) reported reflectance rankings in the IR range when treatments were consistent between years and reported that lowest reflectance was recorded in soil followed by weed free and highest reflectance was observed in weed infested areas. Increased reflectance from weed infested areas was most likely due to increased biomass and canopy cover.

Radiance ratio (RR)

The data on red reflectance and infra-red reflectance of the crop under different treatments was collected and from this data radiance ratio of the crop was calculated. Fig 3 depicted the graphical presentation of the radiance ratio under different population levels of *Malva neglecta* during both the years of investigation. Data revealed that with advancement in growth stages there was increase in the radiance ratio irrespective of the wheat or weeds. Radiance ratio increased up to 90 DAS followed by sharp decline in the value. Decrease in radiance ratio at 90 DAS was due to more scattering of light in the inter-cellular space and less reflectance of NIR band relative to the red band. The solid wheat stand had highest RR value compared to rest of the treatments and minimum was recorded in pure weed treatment, i.e.T_6. Gibson *et al.* (2004) support the idea that remote sensing has potential for weed detection in soybean, particularly when weed management systems do not require differentiation among weed species. Everitt *et al.* (1992) reported that Drummond and common golden weed can be separated from other plant species and soil at flowering in the fall. Leafy spurge produces showy yellow bracts in late May of early June giving the plant a conspicuous appearance so it might be distinguishable on aerial imagery in this phonological stage. Optimum time span for distinguishing little seed canary grass (*Phalaris minor*) and *Avena ludoviciana* from wheat (*T. aestivum* L.) crop based on their spectral reflectance characteristics was studied and it was reported that it is possible to discriminate *P. minor* as well as *A. Ludoviciana* from wheat crop based on their spectral signatures.

Normalized difference vegetation index (NDVI)

A plethora of remote sensing indices have been developed for use in remote sensing research over the past 30 years, but the normalized difference vegetation index (NDVI) has become the most popular. By contrasting a plant's characteristically low red reflectance with its high IR reflectance, vegetation indices such as the NDVI, can accurately distinguish pure vegetation spectra from that of other pure spectra such as soil, water and rock. Thenkabail *et al.* (2000) found that LAI and biomass were highly correlated with vegetation indices than crop height and canopy cover. Fig 4 represents the values of NDVI calculated for the different treatments having variable population of *Malva neglecta* (2010-11 and 2011-12 respectively). Figure shows that NDVI was going on increasing with advancement in crop age, reaching maximum at 90 DAS and then decreased. This reduction in NDVI was because of decrease in absorption of light in the red region owing to cell degeneration and decrease in LAI. Among all the treatments, slid stand of wheat crop, i.e. T_1 showed the highest NDVI values. The various population levels of weed specie can be distinguished from pure wheat crop at 30 DAS. The perusal of RR (Fig 3) and NDVI (Fig 4) data revealed that both spectral indices were equally good in distinguishing *Malva neglecta* weed plant in wheat crop. Aparicio *et al.* (2000) reported that LAI was the crop growth trait that most closely correlated with the spectral reflectance indices. They further studied that when all genotypes, growth stages and environments measured were considered together, a positive linear relationship between simple ratio (SR) and LAI was observed. In contrast the relationship between NDVI and LAI was exponential, with NDVI increasing rapidly, reaching LAI values of about 3. At this stage NDVI tended to reach an asymptote at values between 0.8 and 0.9. A significant relationship between NDVI and soil water potential was reported by Yang and Su (2000), the increasing of soil water stress with decreasing value of NDVI. The highest RR and NDVI values were recorded under solid stand of wheat treatment and lowest under pure weed treatments. This may be due to dark green colour and better vigour of the wheat as compared to weed species. It was observed that by using RR and NDVI, pure wheat can be distinguished from pure populations of *Malva neglecta* after 30 DAS and different weed population densities can be discriminated amongst themselves from 60 DAS during both the years of investigation. Goel *et al.* (2003) reported that commercially available multispectral aerial imagery at current spatial resolutions does not provide consistently reliable data for detection of early season weeds in glyphosate-resistant corn cropping systems. Additional refinement in sensor spatial and spectral resolution is necessary to increase our ability to successfully detect early season weed infestations. Stepwise discriminant function analyses showed that reflectance in the visible and "red-edge" regions of the spectrum were consistently required for species discrimination. The seven species were correctly identified 90 and 89% of the time using the hyperspectral and multispectral data, respectively, and the classification rules derived from discriminant function analyses (Anne and Robert 2003). The efficiency of these wavebands and indices were studied by using color and color-infrared aerial images taken over three naturally infested fields. In StaCruz, areas infested with wild oat and canary grass patches were discriminated using the indices R, NIR, and NDVI with overall accuracies (OA) of 0.85 to 0.90. In Florida–West, areas infested with wild oat, canary grass, and ryegrass were discriminated with OA from 0.85 to 0.89. In Florida–East, for the discrimination of the areas infested with wild oat patches, visible wavebands and several vegetation indices provided OA of 0.87 to 0.96. Estimated grass weed area ranged from 56 to 71%, 43 to 47%, and 69 to 80% of the field in the three locations, respectively, with per-class accuracies from 0.87 to 0.94. NDVI was the most efficient vegetation index, with a highly accurate performance in all locations. Our results suggest that mapping grass weed patches in wheat is feasible with high-resolution satellite imagery or aerial photography acquired 2 to 3 wk before crop senescence (Francisca *et al.* 2006).

It is clear from the results that pure wheat stand can be easily distinguished from pure weed stand of *Malva neglecta* just after 30 DAS. NDVI and radiance ratio (RR) are the most reliable remote sensing indices to distinguish higher population levels of *Malva* like 6, 9, 12 plants/m^2 from the pure wheat crop, but lower population level, i e 3 plants/m^2 is somewhat difficult to distinguish from pure wheat stand at 30 DAS as well as 60 DAS. From the study it was concluded that remote sensing can be used for identification of different weed infestations in crops and weed prescription maps can be prepared with Geographic Information System (GIS), on the basis of which farmers can be advised to take the preventive control measures.

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