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Prediction of Chilli Yields based on Soil Nutrient Status under Rainfed Conditions of Dharwad District, Karnataka

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ABSTRACT : A study was undertaken to assess the nutrient status and yield of major rainfed chilli growing areas of Kundgol and Hubli taluks of Dharwad district, Karnataka. The analysis of soil samples from the selected chilli fields revealed that the soils were neutral to alkaline in reaction with normal electrical conductivity. Organic carbon content of soils was low to medium. Soils were low to medium in available nitrogen, medium to high in available phosphorus and high in available potassium status. Significant correlations were obtained between yield and applied nutrients, normalized difference vegetation index (NDVI) and leaf area index (LAI) of chilli crop in both the taluks. The multiple regression equations developed between yield and applied nutrients in terms of NPK, yield, NDVI and LAI also showed significant coefficient of determination in Kundgol (R^2= 0.755 and R^2 = 0.851) and Hubli taluks (R^2= 0.874 and R^2= 0.877).

Chilli (*Capsicum annuum* L.) is one of the most valuable commercial spice crops grown throughout India in diverse climatic conditions. Chilli is grown in all the districts of Karnataka, but the major chilli growing districts are Dharwad, Haveri and Gadag. In these districts, chilli is mostly grown as rainfed crop. Most of the chilli growing area in Dharwad district is concentrated in Kundgol and Hubli taluks. Chilli grown in some of the villages of Kundgol taluk is of the best quality and fetches higher price in world market. It is grown as a pure crop in Kundgol taluk, whereas chilli + cotton or chilli + cotton + onion mixed cropping is prevalent in Hubli taluk. Among production constraints, low soil fertility is a major limitation for increasing productivity of dryland crops. Low and erratic rainfall, degraded soils with low available water and multi-nutrient deficiencies are important factors contributing to low crop yields in rainfed production systems. Emerging macro nutrient deficiencies in these production systems were reported by Srinivasarao *et al.* (2006). The present investigation was undertaken to assess the nutrient status of chilli growing soils, rate of application of nutrients and the crop yields under rainfed environment.

Materials and Methods

Kundgol and Hubli taluks of Dharwad district come under Northern Transitional Zone of Karnataka. The average rainfall of the region ranges from 626 to 727 mm. The total rainfall received during the cropping season was 831 mm in Kundgol taluk and 633 mm in Hubli taluk. A total of 62 chilli fields were selected from both the taluks after conducting preliminary survey of the study area and verification of statistical data on extent of chilli area.

Soil samples (0-30 cm depth) were drawn from the selected chilli fields and the samples were air dried in shade, then ground and sieved through 2 mm sieve for physico-chemical analysis. The soil pH and electrical conductivity (EC) was determined in 1:2.5 soil water suspension using Systronics 331 pH meter and Systronics 334 conductivity bridge (Jackson, 1973). Organic carbon was estimated by chromic acid digestion (Walkley and Black, 1934), available nitrogen by alkaline potassium permanganate method (Subbiah and Asija, 1956), available phosphorus by Olsen's extractant (Olsen *et al.*, 1954) and available potassium by neutral

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normal ammonium acetate (Jackson, 1973) using Flame photometer. The surface soil samples were classified into low, medium and high categories as per the limits suggested by Muhr *et al.* (1965) for available N, P and K and organic carbon.

The information on the amount of manures and fertilizers applied to chilli crop was collected from the farmers and the quantity of nutrients applied in terms of nitrogen, phosphorus and potassium (kg ha^{-1}) was calculated. Randomly selected 10 m x 10 m sampling unit from each field was used to measure the yield attributes and yield of chilli crop. The GARMIN 12 GPS receiver in standalone mode was used to collect the information regarding the geographical location of the ground truth sites, which is used for marking of training sites. The LAI 2000 plant canopy analyzer (LICOR) was used to record the leaf area index (LAI) in the standing crop of chilli. IRS ID LISS III digital image of Kundgol and Hubli taluks corresponding to path 97 and row 62 acquired on the 14^{th} of November 2002, which coincides with the maximum vegetative growth to fruit ripening stage of chilli crop was used for obtaining normalized difference vegetation index (NDVI). Digital analysis of satellite data was carried out for deriving information on spatial extent of chilli crop grown in the study area. The IBM RS workstation with ERDAS IMAGINE 8.5 software at National Remote Sensing Agency, Hyderabad, was used for the analysis and interpretation of remote sensing data. Geometric correction of the image was done using SOI toposheets of 1:50,000 scale. Normalized Difference Vegetation Index (NDVI) proposed by Rouse *et al.* (1974) was used in this study. The red and near infrared channel data pertaining to the IRS ID LISS III digital image were transformed into NDVI image in ERDAS IMAGINE Modeler panel by running the NDVI model. The NDVI values from resultant NDVI image of the chilli crop were used for developing yield prediction equation.

The correlation coefficients were worked out and polynomial regression equation was run between the yield and independent variables affecting the yield like applied nutrients in terms of Nitrogen, Phosphorus, Potassium, NDVI, LAI during the crop growth period for developing yield prediction equations.

Results and Discussion

Physico-chemical properties of soils

The pH of the soils ranged from 6.40 to 8.0 with a mean value of 7.25 in Kundgol taluk indicating that the soils were neutral and slightly tending towards alkalinity, whereas in case of Hubli taluk, the soils were slightly acidic to alkaline with pH ranging from 6.40 to 9.32 with a mean value of 7.65 (Table 1).

Electrical conductivity varied from 0.13 to 0.33 dS m^{-1} with mean values of 0.20 dS m^{-1} in Kundgol taluk and 0.22 dS m^{-1} in Hubli taluk. All the soils were normal in electrical conductivity.

The organic carbon content in the soils of Kundgol taluk ranged from 0.21 to 0.87 per cent with a mean value of 0.61 and SD of 0.13, where as it varied from 0.42 to 0.82 per cent with mean and SD of 0.59 and 0.12, respectively in Hubli taluk (Table 1). The low organic carbon content in some of the areas might be due to lower rates of application of organic manures and greater dependence on inorganic fertilizers.

Available Nitrogen

The available nitrogen content varied from 97 to 339 kg ha^{-1} with mean value of 176.82 kg ha^{-1}, SD of 50.85 kg ha^{-1} in Kundgol taluk. The soils were low (94%) to medium (6%) in available nitrogen status. In Hubli taluk, the available nitrogen content ranged from 92 to 354 kg ha^{-1} with a mean and SD of 161.57 and 56.6 kg ha^{-1}, respectively (Table 1). Only 4 per cent of the soils in Hubli taluk were medium in available nitrogen and rest all were low. Low available nitrogen could be attributed to low organic carbon content in soils. The higher nitrogen content in some of the soils may be due to the very fine texture of soils on account of higher clay content, which results in reduced leaching of applied nitrogen and also due to heavy application of manures and fertilizers every year to get high yields.

Available Phosphorus

The available phosphorus content ranged from 12 to 26 kg ha^{-1} with mean and SD of 19.27 and 3. 8 kg ha^{-1}, 12 to 39 kg ha^{-1} and 24.15 and 6.58 kg ha^{-1}, respectively in Kundgol and Hubli taluks (Table 1). The available phosphorus content was medium to high in most of the soils of Kundgol and Hubli taluks. This may be due to addition of organic manure and complex fertilizers containing phosphorus. Lower phosphorus content in some of the soils may be due to reduced rates of application of manures and fertilizers as well as the presence of excess calcium carbonate forming insoluble compounds of calcium and phosphorus leading to reduction in phosphorus availability. Bidari (2000) also reported similar results for black soils of Dharwad district.

Available Potassium

The available potassium content ranged from 320 to 590 kg ha^{-1} in soils of Kundgol taluk with mean and SD value of 421.94 and 58.95 kg ha^{-1}, respectively and 350 to 614 kg ha^{-1} with mean and SD of 478.3 and 84.14 kg ha^{-1} in Hubli taluk (Table 1). The available potassium content was high in both the taluks. In general, black soils are high in available potassium content. In addition to this, potassium from organic matter and fertilizers might have led to higher exchangeable potassium in soils as reported by Chahal *et al.* (1976). This exchangeable potassium is the major contributor for available potassium in soil.

Table 1 : Soil chemical properties, NDVI and LAI of selected chilli growing fields of Kundgol and Hubli taluks

Taluk		pH	EC (dS m^{-1})	OC (%)	Av. N (kg ha^{-1})	Av. P (kg ha^{-1})	Av. K (kg ha^{-1})	NDVI*	LAI**
Kundgol	Minimum	6.40	0.13	0.21	97	12	320	0.441	1.53
(36 samples)	Maximum	8.01	0.33	0.87	339	26	5900.	107	0.12
	Mean	7.25	0.20	0.61	177	19	422	0.236	0.55
	SD	0.35	0.06	0.13	51	4	59	0.083	0.35
Hubli	Minimum	6.40	0.13	0.42	92	12	350	0.456	1.80
(26 samples)	Maximum	9.32	0.33	0.82	354	39	614	0.113	0.19
	Mean	7.65	0.22	0.59	162	24	478	0.217	0.55
	SD	0.69	0.05	0.12	56	7	84	0.091	0.36

*NDVI: Normalized differential vegetation index; **LAI: Leaf area Index

Relationship between yield of chilli and applied nutrients, NDVI and LAI

Nutrient supply is one of the most important factors that determine the growth of crop and ultimately yield. The quantity of applied nutrients varied from 54-8-11 kg NPK ha^{-1} to 227-42-83 kg NPK ha^{-1} in Kundgol taluk and 24-7-11 to 106-29-83 kg NPK ha^{-1} in Hubli taluk.

In the present investigation, the yield levels of chilli crop differed due to the different levels of manures and fertilizers applied by the farmers. In Kundgol taluk, the highest yield recorded was 1280 kg ha^{-1} with application of 227-97-100 kg NPK ha^{-1} and lowest yield of 136 kg ha^{-1} with application of 60-19-19 kg NPK ha^{-1}. Whereas, in Hubli taluk, the highest yield recorded was 1544 kg ha^{-1} where the farmer had applied 106-68-100 kg NPK ha^{-1} and lowest yield was 111 kg ha^{-1} in the field which received only 24-17-13 kg NPK ha^{-1}. The main reason for low and variable yields at different places was low and erratic distribution of rainfall during the crop growth period.

The observations from the selected ground truth sites in Kundgol and Hubli taluks indicated that the LAI values at the time of the satellite data acquisition varied from 0.12 to 1.53 in Kundgol taluk and 0.19 to 1.80 in Hubli taluk. The NDVI value of chilli crop ranged from 0.1071 to 0.4412 in Kundgol taluk and from 0.1132 to 0.4559 in Hubli taluk.

The regression analysis between yield and applied nutrients in terms of NPK kg ha^{-1} showed significant correlations between yield and applied nitrogen (r = 0.809 and 0.607), phosphorus (r = 0.785 and 0.676) and potassium (r = 0.767 and 0.863), respectively in Kundgol and Hubli taluks (Table 2).

Table 2 : Results of the linear regression analysis between nutrients applied, NDVI, LAI and Yield of chilli crop

Variable	Correlation Coefficient Values	
	Kundgol	Hubli
Nitrogen	0.809*	0.863**
Phosphorus	0.785*	0.676*
Potassium	0.767*	0.607**
NDVI	0.909**	0.896*
LAI	0.900*	0.920**
	* Significant at P = 0.05	** Significant at P = 0.01

In Hubli taluk, even though the potassium application through inorganic fertilizers is comparatively less and applied only in very limited number of fields, the applied potassium in the form of FYM showed highly significant correlation with yield (r=0.863). Significant correlation between yield and applied nutrients in Kundgol taluk may be due to comparatively higher rainfall than Hubli taluk which might have helped in better uptake of the nutrients by the crop. In places where the rainfall was not sufficient and there was no provision for supplementary irrigation, the yields were low despite application of considerable quantity of FYM and fertilizer. The regression analysis between yield and NDVI, LAI also showed significant correlations between yield and NDVI (r = 0.909 and 0.896) and LAI (r = 0.900 and 0.920), respectively in Kundgol and Hubli taluks (Table 2). Martin and Heilman (1986) and Sridevi (2002) also reported significant correlation between NDVI and LAI, NDVI and yield components of rice crop.

Multiple Regression equations for Yield prediction

Yield and Applied Nutrients

A multiple regression analysis was done between yield and applied nutrients. The following were the yield models obtained for yield prediction in Kundgol and Hubli taluks.

Kundgol : $Y = -11.92 + 2.486\,N + 4.218\,P + 4.156\,K$
$R^2 = 0.755$, SEE = 119.9 and F-Ratio = 32.9

Hubli : $Y = -271.71 + 5.053\,N + 3.669\,P + 8.517\,K$
$R^2 = 0.874$, SEE = 124.48 and F-Ratio = 50.81

NDVI, LAI and Yield

A multiple regression analysis was done between yield, NDVI and LAI. The following were the yield models obtained for yield prediction in Kundgol and Hubli taluks.

Kundgol : $Y = -59.55 + 1563\,NDVI + 290.05\,LAI$
$R^2 = 0.851$, SEE = 92 and F-Ratio = 94.49

Hubli : $Y = -165.40 + 1333.50\,NDVI + 532.99\,LAI$
$R^2 = 0.877$, SEE = 120.28 and F-Ratio = 81.93

The yield prediction equations developed using the information on applied nutrients were found to be significant for both Kundgol ($R^2 = 0.755$) and Hubli ($R^2 = 0.874$) taluks, which can explain 75 % and 87 % of variability in yield estimation in Kundgol and Hubli taluks, respectively. The yield prediction models developed using NDVI and LAI were also found to be significant for both Kundgol (r^2=0.851) and Hubli (r^2=0.877) taluks, which explains 85 per cent and 87 per cent of the variability in yield estimation.

The results indicated that most of the soils were neutral to alkaline and non-saline, low to medium in organic carbon and available nitrogen. Available phosphorus was medium to high and all the soils were rich in potassium. Among the applied nutrients, highest correlation was obtained between nitrogen and yield in both Kundgol (r = 0.809) and Hubli (r = 0.863) taluks. Hence, there is a need for better nitrogen management in order to achieve higher yields of chilli crop under rainfed conditions in Kundgol and Hubli taluks of Dharwad district, Karnataka.

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