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RESEARCH ARTICLE

EMPIRICAL MODEL FOR PREDICTION OF MOTIHARI TOBACCO (*NICOTIANA RUSTICA*) LEAF QUALITY BASED ON LEAF NUTRIENTS AND SOIL FERTILITY

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ABSTRACT

The tobacco cured leaf yield as well as leaf quality are important factor which determined market price and net return. The yield and leaf quality of tobacco influenced by a numbers of factors such as varieties, soil, irrigation water and management practices. The nutrient composition and quality constituents like nicotine and reducing sugars in the leaf are influenced by the availability of nutrients in the soil. The permanent manorial trial has been started in 1961-62 and till now continuing at CTRI Research Station, Dinhata. Database is being maintained for this trial and the data for last 10 years (2004-05 to 2014-15) was collected on first grade leaf yields was collected along with Leaf composition i.e. Nitrogen, Phosphorus, Potassium, Chloride, Nicotine and reducing Sugar contents and soil nutrients data including OC (g kg^{-1}), available P_2O_5 (kg ha^{-1}), Available K_2O (kg ha^{-1}) and Chloride (ppm) content. Relationship among the quality constituents and composition of leaf and soil fertility was developed using regression analysis. Nitrogen fertilization played crucial role for leaf yield, quality and nicotine content in leaf and recorded positive relationship with them. The nicotine and nitrogen content showed significant ($P<0.01$) positive relationship with linear regression equation was $Y=79.041x-1412.2$. However, reducing sugar content in leaf showed negative relation with phosphate in leaf with regression equation $Y=-2.610x+16.94$. The soil content of K_2O showed significant positive relationship with leaf Potassium content. The result showed that nitrogen and phosphate fertilization may regulate nicotine and reducing content of leaf.

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INTRODUCTION

Motihari tobacco (*Nicotianarustica*) is cultivated in North Bengal for its chewing quality and high nicotine content. In this tobacco nicotine content was highest (4.83-6.64 %) compared to other tobacco cultivated in India except bidi tobacco (9.71%) (Reddy *et al*., 2013). The tobacco cured leaf yield as well as leaf quality are the important factors which determined market price and net return. Leaf composition including Nicotine, reducing sugar, Nitrogen, Phosphate, Potassium and chloride contents will determine the leaf quality and their contents are influence by various factors such as available soil nutrients, varieties, climate and management practices (Filiposki *et al*.,1990; Marmat 1997; Farrokh *et al*., 2012; Kumar *et al*., 2013; Wu *et al*., 2013). The leaf quality depends on relative concentration of various organic compounds such as total alkaloids and reducing sugars (Meiner *et al*., 1990). The total alkaloids content was higher in treatments with using mineral nitrogen (Jones 1988). With increased application of nitrogen, not only increased the alkaloid and nitrogen content of leaf but also growth and yield of tobacco (Mylonas *et al*., 1981; Jeong *et al*., 1986). Organic matter and total nitrogen contents in the soil were correlated positively with nicotine content in cured leaf and total nitrogen in the soil negatively with total sugar content in cured leaf (Jeong 1986). Management practices such as type of fertilizer applied is one of the most crucial factors which may determine quality of tobacco. For chewing tobacco, generally Murate of Potash is applied due to its low market price than Potassium sulphate, where chlorine content in leaves in not a concern with quality of chewing tobacco. However, for FCV tobacco, potassium sulphate is applied because murate of potassium affects the burning property of tobacco due to its chloride content (Sabeti *et al*., 2013).The increased levels of K was not influenced the cured leaf yield and quality parameters like nicotine, reducing sugars and chlorides. However, burn related issue showed positive response to higher doses of

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Kupto180kg/ha (Mahadevaswamy 2013). In K-deficient crops, the supply of sink organs with photosynthates is impaired and sugars accumulate in source leaves. This not only affects yield but also quality parameters. Potassium plays a prominent role in crop resistance to drought, salinity, high light, or cold as well as resistance to pests and pathogens (Zorb *et al*., 2014). To produce less harmful tobacco, it may be possible through altering leaf composition or others external factors like nutrients supplied by soil, management practices and crop varieties. For producing high or less nicotine and reducing sugar content in tobacco leaf, availability of nitrogen, phosphate, potassium and chlorideby soil may play vital role. The aim of present study is to develop empirical models to predict the leaf quality based on leaf composition and effect of soil fertility on leaf composition.

MATERIALS AND METHODS

Experimental site and treatments details

Permanent manorial trial has been started in 1961-62 and till now continuing at CTRI Research Station, Dinhata. The site situated $26^0 21^/$ N latitude, $899^0 27^/$ E longitude with 43 msl. The experiment has 10 treatments (Table-1). All the nutrients applied in the form of Urea, Single Super Phosphate and Murate of Potash. The half dose of nitrogen along with full doses of Phosphate and Potassium applied as basal and remaining half dose Nitrogen applied at the time of irrigation (45 days after planting). Well rotten FYM applied in required dose before one month planting of seedling. Plot size has been6.3 m X 5.4m since it was started.

Table 1. Treatments details with organic and inorganics fertilizers

Treatments with doses
T1-Control- 10t ha^{-1} FYM
T2-N 112 kg ha^{-1} + 10t ha^{-1} FYM
T3-$P_2O_5$112 kg ha^{-1} + 10t ha^{-1} FYM
T4-K_2O112 kg ha^{-1} + 10t ha^{-1} FYM
T5-N+ P_2O_5 112 kg ha^{-1} each + 10t ha^{-1} FYM
T6-N+ K_2O 112 kg ha^{-1} each + 10t ha^{-1} FYM
T7-P_2O_5+ K_2O 112 kg ha^{-1} each + 10t ha^{-1} FYM
T8-N+ P_2O_5 + K_2O 112 kg ha^{-1} each + 10t ha^{-1} FYM
T9-FYM 25t ha^{-1}
T10-FYM 50t ha^{-1}

Soil and leaf composition analysis

The soil sample collected immediately after harvesting of crop every year at the depth of 0-15cm for analysis of organic carbon, available Phosphorus, Potassium and Chloride follows the procedure (Table2), whereas tobacco cured leaf was used for leaf composition estimationsas given in Table 2.

Data collection and statistical analysis

Ten years of this trial (2005-06 to 2014-15) on first grade leaf yield (kg ha^{-1}) along with leaf composition i.e. Nitrogen, Phosphorus, Potassium, Chlorine, Nicotine and Reducing Sugar was collected and simultaneously soil nutrient data such as OC (g kg^{-1}), available P_2O_5 (kg ha^{-1}), Available K_2O (kg ha^{-1}) and Chloride content (ppm) was collected for last ten years with respect to leaf composition.

The linear regression analysis was made first grade leaf yield with Nicotine, Reducing sugar, Nitrogen, Phosphate, Potassium, Chlorine content in leaf and leaf Nicotine and reducing sugar content with leaf Nitrogen, Phosphorus, Potassium and Chloride content. However, multiple regression analysis was made for leaf Nitrogen, Phosphate, Potassium and Chlorine with soil Organic carbon, N, P_2O_5, K_2O and Chloride content to find relationship among them. Regression equations were developed using Microsoft excel.

Table 2. Methods used for estimation of soil and leaf composition

Soil analysis	Reference
Organic carbon	Walkey *et al*., 1934
Phosphorus	Bray *et al*.,1945
Potassium and Chlorine	Jackson 1967.
Plant analysis in tobacco leaf	
Nitrogen, Phosphorus and Potassium	Jackson 1967.
Nicotine and Reducing sugar	Harvey *et al*.,1969
Chlorine	Hanumantharao *et al*., 1980

RESULTS AND DISCUSSION

Quality of tobacco leaf is a most important aspect which determined market price and economic return. Quality will be determined by various factors including soil supplied essential elements play important role which may be inherent capacity of soil or external input by various form. Balanced application of NPK with organic manures recorded the highest quality leaf and also found Nitrogen application alone or with other nutrient combination found to be produced more quality leaf than treatment without nitrogen application (Fig-1). Singh *et al*. (2002) reported that with increase in nitrogen dose from 0 to 56 Kg and further to 112 Kg ha^{-1} increased total cured and first grade leaf yields. Long term application of 25t ha^{-1} and 50t FYM $ha^{-1}$was not able to produced more quality leaf than treatments nitrogen along and it combination with other nutrients as little nutrients was return to soil after harvesting of tobacco because most of the crop biomass harvested as economic product and small portion remained as crop residue which may incorporate into soil. Integrated use of nutrients in tobacco plays a vital role to produce maximum quality leaf (KasturiKrishna *et al*., 2009). Concern with organic tobacco, it clearly indicated that quality tobacco may not produce alone FYM even high dose. So, nitrogen addition may require through inorganic fertilizer, green manures or other biological means for nitrogen fixation to meet nitrogen demands.

Relationship between the first grade leaf yield with Nicotine, Reducing sugar, Nitrogen, Phosphorus and Chloride in leaf

Among various factors leaf composition is an important factor which may determine quality of tobacco. Relationship between first grade leaf yield with various leaf constituents, only nicotine content and nitrogen content showed significant (P=<0.01) strong positive relation, where with reducing sugar, Phosphorus, Potassium and chloride showed no relation. The slope increased for Nicotine as quality leaf yield increased (Fig-2).

Nicotine conten tin leaf is a key indicator to evaluate the quality of tobacco and with increased application of nitrogen increased nicotine content in leaf (Kena, 1990). Kasturi Krishna *et al*. (2009) reported that N and nicotine content in leaf increased while sugar: nicotine ratio decreased with increased in the level of nitrogen application from 20 to 60 kg ha^{-1}.

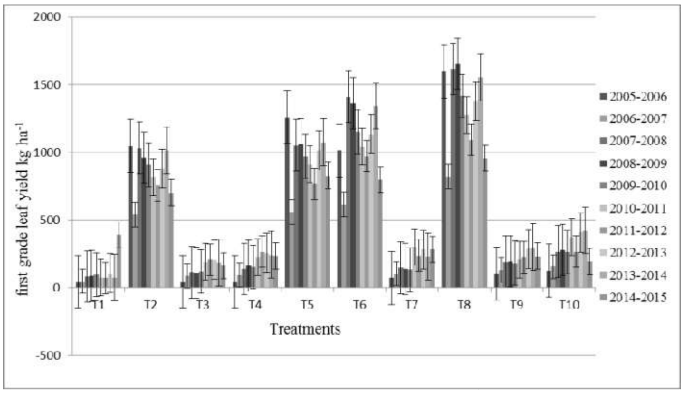

Fig. 1. Effect of different treatments on first grade leaf yield with error bars

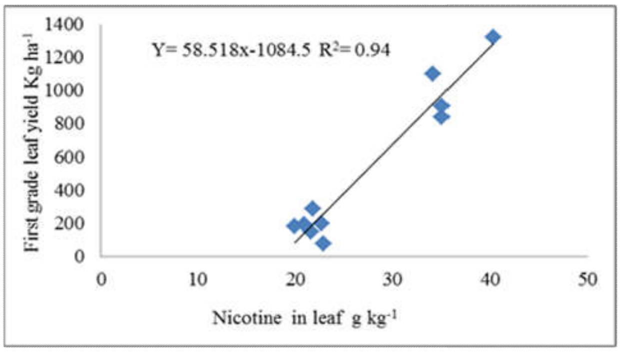

Fig. 2. Relation of First grade leaf with Nicotine

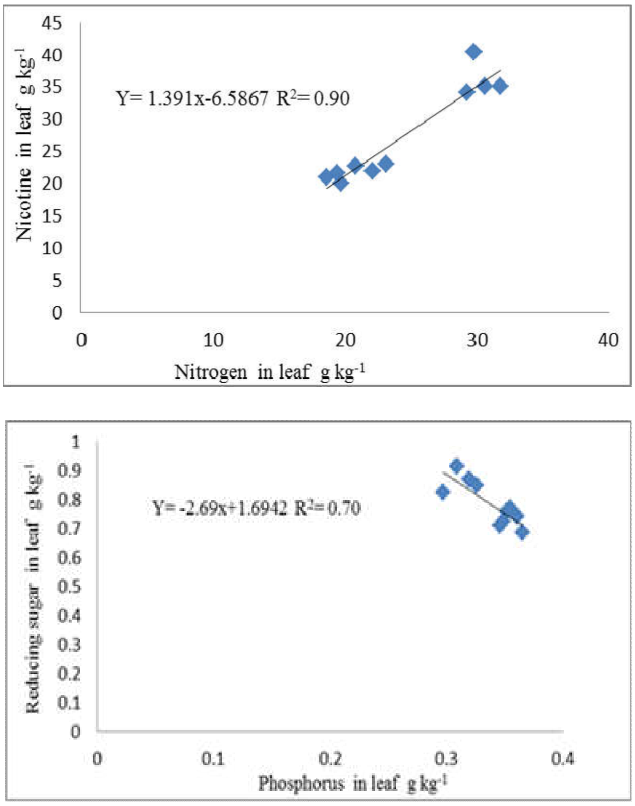

Fig. 1. Relationship leaf content Nicotine with Nitrogen and Reducing sugar and Phosphorus content

Relationship of leaf Nicotine with Nitrogen, Phosphorus, Potassium and Chloride content in leaf

Nicotine content in leaf is influencedby various factors such as varieties, fertility status of soil and leaf composition. Here, relationship was made between Nicotine in leaf with Nitrogen, Phosphorus, potassium and chloride content. Nicotine content in leaf showed significant (P=<0.01) positive relationship with nitrogen content in leaf However, Phosphorus, Potassium and chloride content showed weak positive or negative relationship with nicotine content in leaf (Table 3).

The nicotine is an alkaloid with formula: $C_{10}H_{14}N_2$ in which the nitrogen element in the structure, produced in roots and transported to leaf and increased with increase in application of nitrogen (Haghighi *et al*., 2011). Chai (2012) reported that the applied nitrogen level is closely related to the total nitrogen and nicotine of burley tobacco at growing period and post-air curing and rational application of nitrogen is an important measure to regulate the content of total nitrogen and nicotine of tobacco. Application of increased levels of nitrogen increased the nicotine content in leaf (Ju *et al*., 2008). However, Marchetti *et al*. (2006) reported that with increased application of N fertilizer, increased yield but delayed harvest of leaves.

Table 3. Linear regression analysis of leaf Nicotine with leaf Nitrogen, Phosphorus, Potassium and Chloride

Variables	Intercept (a)	Coefficient (b)	Standard error	MSE	R^2
Nitrogen	-6.59	1.39	0.17	6.87	0.90**
Phosphorus	18.90	2.55	11.56	66.18	0.12^{ns}
Potassium	35.50	-0.43	0.75	64.01	0.08^{ns}
Chloride	24.18	3.09	5.58	64.13	0.08^{ns}

Relationship of reducing sugar content in leafwith Nitrogen, Phosphorus, Potassium and Chloride content in leaves

Reducing sugar content was generally low in chewing tobacco leaf. Its content with leaf nutrients such as Nitrogen, Potassium and chloride showed no relationship. However, Phosphate content showed significant (P=<0.01) negative relation with reducing sugar content in leaf (Table 4). The Phosphate content in leaf increases the slope of curve decreases (Fig-3). Reddy *et al*. (2013) reported that the reducing sugar content in leaf had negative correlation with phosphate. So, phosphate management plays significant role on reducing sugar content in leaf.

Relationship between Soil nutrients with Leaf composition

Soil is a store house of nutrients from where plants take its essential elements for growth and development. Nutrients in soil content remained different forms such as fixed form, exchangeable forms and available nutrients which may be taken up by plant. The availability of nutrients depends on soil water content, texture, nutrients concentration, organic carbon content etc. There was no relation between leaf Nitrogen and phosphate with soil organic carbon, Phosphorus, Potassium and Chloride content in soil (Table 5). However, leaf K uptake showed a significant (P=<0.05) positive relation with availableK_2O and Chloride content in soil (Fig-4). The soil reached with K, plant shows luxurious consumption. Mathew *et al*. (2013) reported that potassium application in soil has no relation with leaf Nitrogen and Phosphate but higher levels of soil K_2O increases the leaf uptake of K.Xu *et al*. (2015) reported that the soil Potassium had positive correlation with potassium content in leaves.

Table 4. Linear regression analysis of leaf reducing sugar with leaf Nitrogen, Phosphorus, Potassium and Chlorine

Variables	Intercept (a)	Coefficient (b)	Standard error	MSE	R^2
Nitrogen	7.34	0.02	0.05	0.691	0.10^{ns}
Phosphorus	16.94	-2.69	0.62	0.19	0.66**
Potassium	8.32	-0.025	0.074	0.631	0.11^{ns}
Chlorine	7.81	0.028	0.56	0.640	0.12^{ns}

Table 5. Relationship of leaf Nitrogen, Phosphate, Potassium and Chloride with soil Organic carbon, N, P_2O_5, K_2O and Chlorine

Nitrogen	$Y=5.81+6.47x-0.48x^2-0.03x^3+0.16x^4$ $R^2=0.5^{ns}$
Phosphate	$Y=0.72+0.18x+0.014x^2+0.002x^3+0.008x^4$ $R^2=0.05^{ns}$
Potassium	$Y=1.66-2.01x+0.02x^2+0.15x^3+0.05x^4$ $R^2=0.57^{*}$
Chlorine	$Y=-1.6-0.13x-0.02x^2+0.02x^{3*}+0.02x^4$ $R^2=0.36^{*}$

*significant at 5% level of significance, ns- non significant

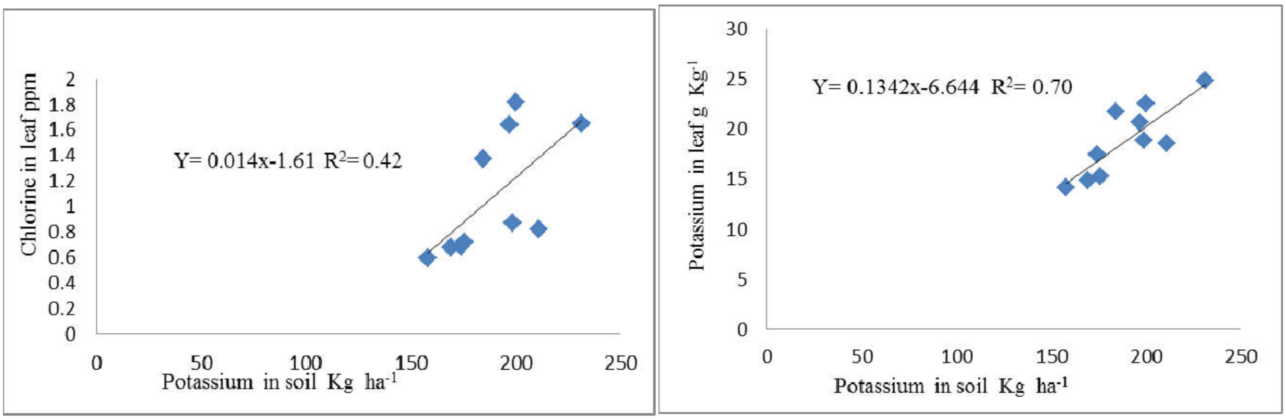

Fig. 4. Relationship between K_2O in soil with Potassium and Chlorine content in leaf

CONCLUSION

Nitrogen play a vital role in the quality of Motihari tobacco (*Nicotianarustica*) and showed synergistic relation with quality leaf yield and can be predicted the first grade leaf yield using regression equation Y=79.041x-1412.2.The nicotine content in leaf may be regulated by nitrogen fertilization as it showed strong positive relation with leaf nitrogen and nicotine content in leaf may be estimate using equation Y=58.52x-1084.5. The reducing sugar content in leaf may be controlled by Phosphate fertilization as showed antagonistic effect with phosphorus content in leaf with a regression equation Y=-2.6106x+ 16.94. However, soil K_2O content showed significant positive relationship with leaf Potassium content as tobacco plant has a luxurious consumption of K.

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