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COMPOSITIONAL NUTRIENT DIAGNOSIS (CND) OF ONION (*Allium cepa* L.)

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Abstract

Nutritional constraints often restrict yields of crops in farmers' fields. Plant nutrient status is currently diagnosed using empirically derived nutrient norms from arbitrarily defined high and low yielding subpopulations above a quantitative yield target. Generic models can assist Compositional Nutrient Diagnosis (CND) in providing a yield cutoff value between high-and low-yielding subpopulations for small databases. The objectives of the present study were to determine minimum bulb yield target of high yielding subpopulations in farmers' fields and to know nutritional difference between high and low yielding subpopulations. Data were collected at random using a survey database of 42 observations from nine districts of northern region of Bangladesh where high yielding varieties of onion (cv. BARi Piaz-1) are being extensively cultivated. Nutrient composition was determined form leaf at 45-50 days after transplanting. Mean, median, minimum, maximum, standard deviations, skewness of yield as well as nutrient concentration for N, P, K, S, Ca, Mg, Na, Zn, Mn, Fe, and B were determined and a R (undetermined elements), which comprises all nutrients not chemically analyzed and quantified in onion. Row centered log ratio and cumulative variance ratio function of each nutrient was calculated. The CND generic model gave 10.61 t/ha as minimum cutoff yield of the high-yield subpopulation. Boron was identified as the core yield limiting nutrient for onion in piedmont plain, floodplain and basin soils of Bangladesh. However, S, N, P, and Zn also play a significant role for increasing bulb yield of onion. Onion in farmers' fields of northern region of Bangladesh may require higher B fertilizer dose for better bulb yield. From the studied piedmont plain, floodplain and basin soils of Bangladesh, the yield limiting nutrients were established the following series: B>S>N>P>Zn>Fe>Ca>K>Mg.

Keywords: Nutritional constraints, nutrient diagnosis, CND, onion.

Introduction

Plant foods contain almost all of the mineral and organic nutrients established as essential for animal and human nutrition, as well as a number of unique organic phytochemicals that have been linked to the promotion of good health. Since the

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19th century, it is well known that plant growth is always limited by the nutrient composition and concentration whose availability in the aerial and root environments start to limit plant growth. Soil fertility is among these governing factors, meaning mineral nutrients might be limited plant growth. Therefore, the appraisal of soil fertility and the assessment of plant mineral requirements are fundamental for crop management. In this context, whole plant or plant-organ testing is widely used because it gives a direct measurement of the actual quantities of nutrients taken up by crop. Plant leaf is considered the most effective organ for this purpose.

Approaches to diagnosing leaf nutrient status include the Critical Value Approach (CVA) (Bates, 1971), the Diagnosis and Recommendation Integrated System (DRIS) (Walworth and Sumner, 1987), and Compositional Nutrient Diagnosis (CND) (Parent and Dafir, 1992; Parent *et al.*, 1994). When selecting nutrient norms, a yield cutoff value is decided arbitrarily for defining a high yield subpopulation. For CVA, the cutoff value is generally 90% to 95% of maximum yield while relating percentage yield to nutrient concentration (Ware *et al.*, 1982), assuming that all nutrients except the one being diagnosed are in sufficient, and no excessive amounts. For DRIS and CND, the high-yield subpopulation is selected from a crop survey database. Walworth and Sumner (1987) proposed to consider variance ratios of nutrient expressions to discriminate between the subpopulations. However, no formal procedure was proposed to optimize the partition. Parent and Dafir (1992) expected that multivariate analysis could provide a means to define the high yield subpopulations. Parent *et al.* (1994) proposed the chi-square distribution function to define a CND threshold value for nutrient imbalance. At local level, small databases are available to define effective nutrient norms as related to yield target (Walworth *et al.*, 1988). Escano *et al.* (1981) pointed out that local calibration improve the accuracy of DRIS diagnosis. However, DRIS provides no generic approach to support local diagnosis of nutrient imbalance using small databases as the CND approach dose it because of the chi-square distribution function support (Parent *et al*., 1994).

Onion (*Allium cepa* L.) is the most important bulb crop of cultivated *Alliums* throughout the world and used as vegetables and spice in different ways. Several factors are responsible for low productivity in onion of which nutrient deficiency is the most important one, which causing considerable losses during the nursery raising, bulb production in field.

Few studies considering tissue analysis in onion (*Allium cepa*) have been developed on the concentration of the nutrients in green portion of onion. In general, N, P, K and micronutrient except Cu and Zn tend to be more in concentration in mature onion than in young ones (Mills and Benton Jones, 1996). The CND improved the yield tissue N relationships as polynomial or liner plateau curves compared with CVA in conifer seedlings, onion and potato (Parent *et al.*, 1995). The CND approach is applicable to small size crop nutrient database for solving nutrient imbalance problems in specific agro-ecosystems (Khiari *et al.*, 2001)

The objectives of the present study were (i) to compute the preliminary CND norms for onion grown on the farmers' field of the northern region of Bangladesh; and (ii) to identify significant nutrient interactions through principal component analyses taking into account of the CND indexes.

Theory of Compositional Nutrient Diagnosis (CND)

As indicated by Parent and Dafir (1992), plant tissue composition forms a d dimensional nutrient arrangement, *i.e.*, simplex (S^d) made of d+1 nutrient proportions including d nutrients and a filling value defined as follows:

$$S^d = [(N, P, K, ..., R_d): N>0, P>0, K>0, ... R_d>0,\ N+P+K+...+R_d = 100] \quad (1)$$

where 100 is the dry matter concentration (%); N,P,K,... are nutrient proportions computed as follows;

$$R_d = 100 - (N+P+K+...) \quad (2)$$

The nutrient proportions become scale invariant after they have divided by geometric mean (G) of the d+1 components including Rd (Aitchinson, 1986) as follows:

$$G = [N x P x K x ... x R_d]^{\frac{1}{d+1}} \quad (3)$$

Row-centered log rations are computed as follows:

$$V_N = 1n\left(\frac{N}{G}\right), V_p = \ln\left(\frac{P}{G}\right), V_K = \ln\left(\frac{K}{G}\right) ..., V_{Rd} = \ln\left(\frac{Rd}{G}\right) \quad (4)$$

and

$$V_N + V_p + V_K + .. + V_{Rd} = 0 \quad (5)$$

Where V_x is the CND row-centered log ratio expression for nutrient X. This operation is a control to insure that V_x computations have been conducted properly. By definition, the sum of tissue components is 100% (Eq. [1]), and the sum of their row-centered log ratios, including the filling value, must be zero (Eq. [5]).

After this stage, it is necessary to iterate a partition of the database between two subpopulations using the Cate-Nelson procedure once the observations have been ranked in a decreasing yield order (Khiari *et al*., 2001). In the first partition, the two highest yield values form one group, and the remainder of yield values forms another group; thereafter, the three highest yield values form the other. This process is repeated until the two lowest yield values forms one group, and the remainder of yield values forms the other. At each iteration, the first subpopulation comprise n_1 observations, and second comprise n_2 observations for a total of n observations ($n = n_1+n_2$) in the whole database.

For the two subpopulation obtained each iteration, one must compute the variance of CND V_x values. Then the variance ratio component X can be estimated as follows:

$$f_1(V_x) = \frac{Variance\ of\ V_x\ n_1\ o\ bservations}{Variance\ of\ V_x\ n_2\ observations} \qquad (6)$$

Where $f_1(V_x)$ is the ratio function between two subpopulation, for nutrient X at the *i*th iteration ($I = n_i$-1) and the V_x is the CND row-centered log ratio expression for nutrient X. The first variance ratio function computed for the two highest yields is put on the same line as the highest yield, thus leaving three empty bottom lines.

The cumulative variance ratio function is the sum of variance ratios at the *i*th iteration from the top. The cumulated variance ratios for a given iteration are computed as a proportion of total sum of variance ratios across all iterations to compare the discrimination power of the V*x* between low-yield and high-yield subpopulations on a common scale. So, the cumulative variance ration function $F^c i\ (V_x)$ can be computed as follows:

$$F^c{}_i(V_x) = \left[\frac{\sum_{i=1}^{n_1-1} fi(Vx)}{\sum_{i=1}^{n_1-1} fi(Vx)}\right][100] \qquad (7)$$

Where n_1-1 is partition number and *n* is total number of observations (n_1+n_2). The denomination is the sum of variance ratios across all iterations, and thus is a constant for nutrient X.

The cumulative function $F^c{}_i(V_x)$ related to yield (*Y*) shows a cubic pattern:

$$F^c i(V_x) = aY^3+bY^2+cY+d \qquad (8)$$

The inflection point is the point where the model shows a change in concavity. It is obtained by delving Eq. [8] twice:

$$\frac{\partial F^{C}{}_{i(Vx)}}{\partial Y} = 3aY^2+2bY+C \qquad (9)$$

$$\frac{\partial^2 F^{C}{}_{i(Vx)}}{\partial Y} = 6aY+2b \qquad (10)$$

The infection point is then obtained by equating the second derivative (Eq. [10]) to zero. Thus the solution for the yield cutoff value is -*b*/3a.

The highest yield cut off value across nutrient expressions can be selected to ascertain that minimum yield target for a high-yield subpopulation will be classified as high yield whatever the nutrition expression.

In this way, the CND norms can be calculated using the means and standard deviations corresponding to the row-centered log ratios V_x of d nutrients for the higher-yield specimens that is V_N*,V_P*,V_K*,...V_R* and SD_N*, SD_K*, ...,SD_R*, respectively.

Once the CND norms are developed, they can be validated by using an independent database. They also can be used for diagnostic purposes as follows:

$$I_N = \frac{(V_N - V_N*)}{SD_N*}\text{ , IP} = \frac{(V_P - V_P*)}{SD_P*}\text{ , IK} = \frac{(V_K - V_K*)}{SD_K*}\text{ ,...,}I_{Rd} = \frac{(V_{Rd} - V_{Rd}*)}{SD_{Rd}*} \qquad (11)$$

Where, IN,..., I_{Rd} are CND indices

Additively or independence among compositional data is ascertained using row-centered log ratio transformation (Aitchison, 1986). The CND indices as defined by Eq. [11] are standardized and linearized variables as dimensions of a circle (d+1=2), a sphere (d+1=3), or a hypersphere (d+1>3) in a d+1 dimensional space. The CND nutrient imbalance index of a diagnosed specimen is its CND r^2 and is computed by:

$$r^2 = I^2_N+I^2_P+I^2_K+...+I^2_{Rd} \qquad (12)$$

Its radius, r, computed from the CND nutrient indices, thus characterizes each specimen. The sum of d+ 1 squared independent, unit-normal variable produces a new variable having a χ^2 distribution with d+1 degrees of freedom (Ross, 1987). Because CND indices are independent, unit-normal variables, the CND r^2 values must have a χ^2 distribution function. This is why it is recommended that the highest yield cutoff value (highest discrimination power) among d+ 1 nutrient computation be relined to calculate the proportion of the low-yield subpopulation below yield cutoff used as critical value for the χ^2 cumulative distribution functions. As defined by Eqs. [11] and [12], the closer to zero that CND indices are, and thus the CND r^2 or χ^2 values are, the higher the probability to obtain a high yield.

Materials and Method

Onion (BARI Piaz-1), the winter season crop was grown on 42 farmers' fields in nine districts, namely Bogra, Pabna, Natore, Rajshahi, Rangpur, Gibandha, Nilphamari, Lalmonirhat and Dinajpur of northern part of Bangladesh. Farmers' nutrient-management practice (FP), which is farmer's traditional nutrient management programme was tested (Saleque *et al.*, 2008). The nutrient doses in FP varied from place to place. For FP, doses of N, P, and K varied from 50 to 170, 10 to 35, and 25 to 60 kg/ha, respectively. At 45-50 days after sowing

(DAS), the green portion or leaf was sampled from each plot for determining nutrient concentration. The leaf sample was dried at 69^0C for 72 hr and grinned by Wiley mill. The ground sample was digested with concentrated H_2SO_4 and total N concentration was determined by micro Kjeldahl distillation (Yoshida *et al.*, 1976). The concentration of P, K, Ca, Mg, S, Na, Zn, Fe, Mn, and B was analyzed by digesting a 0.5 g leaf sample with 10 ml 5:2 HNO_3: $HClO_4$ (Yoshida *et al.*, 1976). Leaf nutrients concentration was analyzed and nutrient ratios were calculated. Descriptive statistics were determined for leaf nutrient concentration and nutrient ratio expression data. Statistical parameters were evaluated using Excel software and included, means, variances, CVs and skewness values, where a skewness value of zero indicates perfect symmetry and values greater than 1.0 indicate asymmetry. Following CND equations (1-10) as described in theory (page 3-5) the required parameters were calculated. All computations were made using Excel software (Microsoft, 2007).

Results and Discussion

The cut off yield between the low and high yielding subpopulations obtained from cumulative variance ratio functions of N, P, S, Ca, Mg, Na, K, Zn, Mn, Fe, and B ranged from 9.77 to 10.61 t/ha (Fig. 1- 6 and Table 1). These nutrients are usually deficient in the study area and fertilizer application for these nutrients is recommended. The cutoff yield between the low and high yield subpopulations was determined after examining the five cubic cumulative variance ratio functions $F^c_i(V_x)$, $F^c_i(V_N)$, $F^c_i(V_P)$, $F^c_i(V_K)$, $F^c_i(V_S)$, $F^c_i(V_{Ca})$, $F^c_i(V_{Mg})$, $F^c_i(V_{Na})$, $F^c_i(V_{Zn})$, $F^c_i(V_{Mn})$, $F^c_i(V_{Fe})$ and $F^c_i(V_B)$.The yields (t/ha) at inflection points of the cubic functions, computed by setting the second derivative of $F^c_i(V_x)$ to zero were 10.47t/ha for F^c_i (V_N), 10.42t/ha for F^c_i (V_P), 10.22t/ha for F^c_i (V_K), 10.60t/ha for F^c_i (V_S), 10.21t/ha for F^c_i (V_{Ca}), 10.20t/ha for F^c_i (V_{Mg}), 9.77t/ha for F^c_i (V_{Na}), 10.34t/ha for F^c_i (V_{Zn}), 9.98t/ha for F^c_i (V_{Mn}), 10.37t/ha for F^c_i (V_{Fe}) and 10.61t/ha for F^c_i (V_B), respectively. The highest cutoff yield was obtained with F^c_i (V_B) yield cutoff, 5 to 42 observations had yield of 10.61t/ha or more. Summary statistics for high and low–yielding subpopulations of onion bulb yield and leaf nutrient concentration are given in Table 2. The mean concentration of N, P, K, S, Ca, Mg, Na, Zn, Mn, Fe, and B was higher in high yielding subpopulations, however, the differences was greater in case of Zn. Mean Zn concentration in high yielding subpopulation was 0.03mg/kg compared to 0.002mg/kg in low yielding subpopulation. The sufficient range of onion is 50-60 g/kg for N, 3.5-5.0 g/kg for P, 40-55 g/kg for K, 10-35 g/kg for Ca, 3-5 g/kg for Mg, 5-10 g/kg for S, 22-60 mg/kg for B, 60-300 mg/Kg for Fe, 50-250 mg/Kg for Mn and 16-45 mg/Kg for Zn (Campbell, 2000, Uchida, 2000, Caldwell, 1991, Hochmuth *et al.*, 1991 Plank, 1989 and Pankov, 1984). Onion in the study area suffered from N,

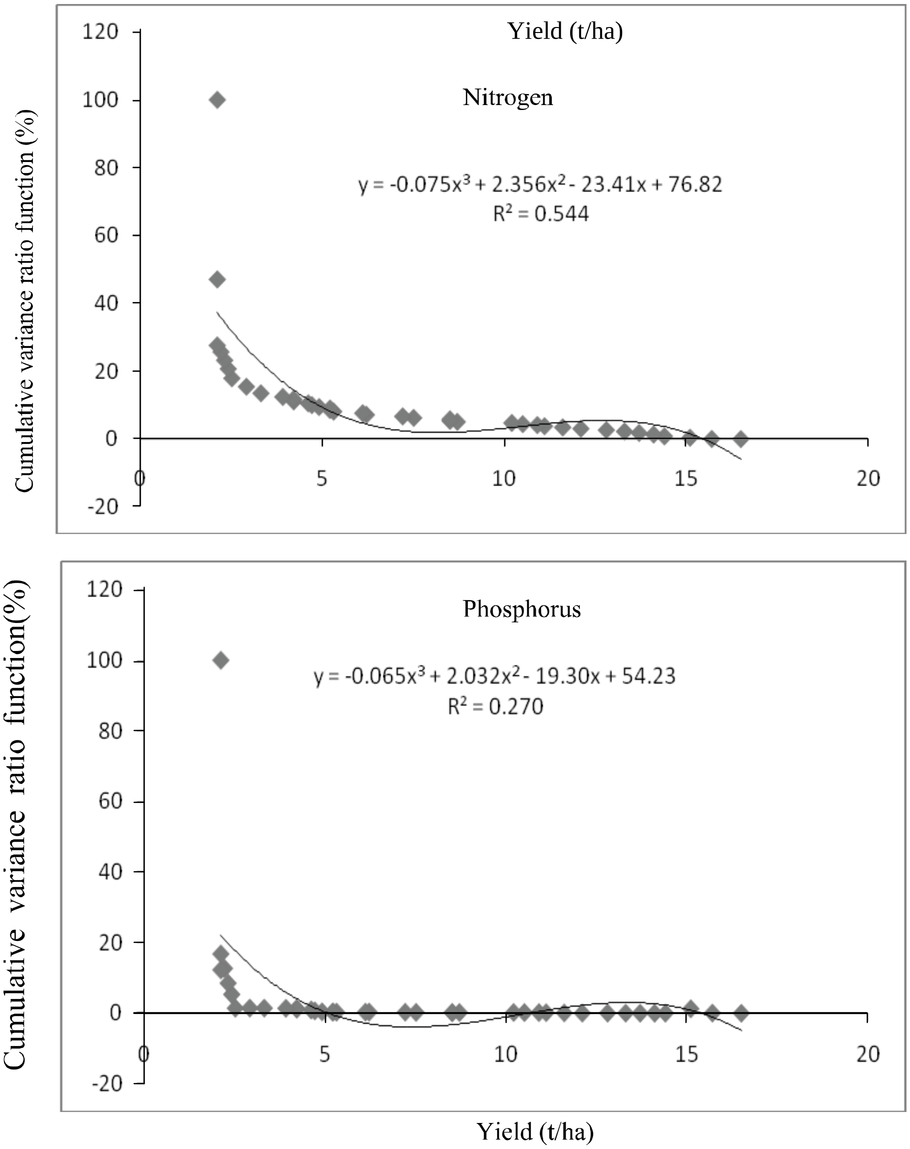

Fig. 1. Relationship between bulb yield of onion (BARI Piaz-1) and cumulative variance ratio function in N and P in farmers' field (n=42).

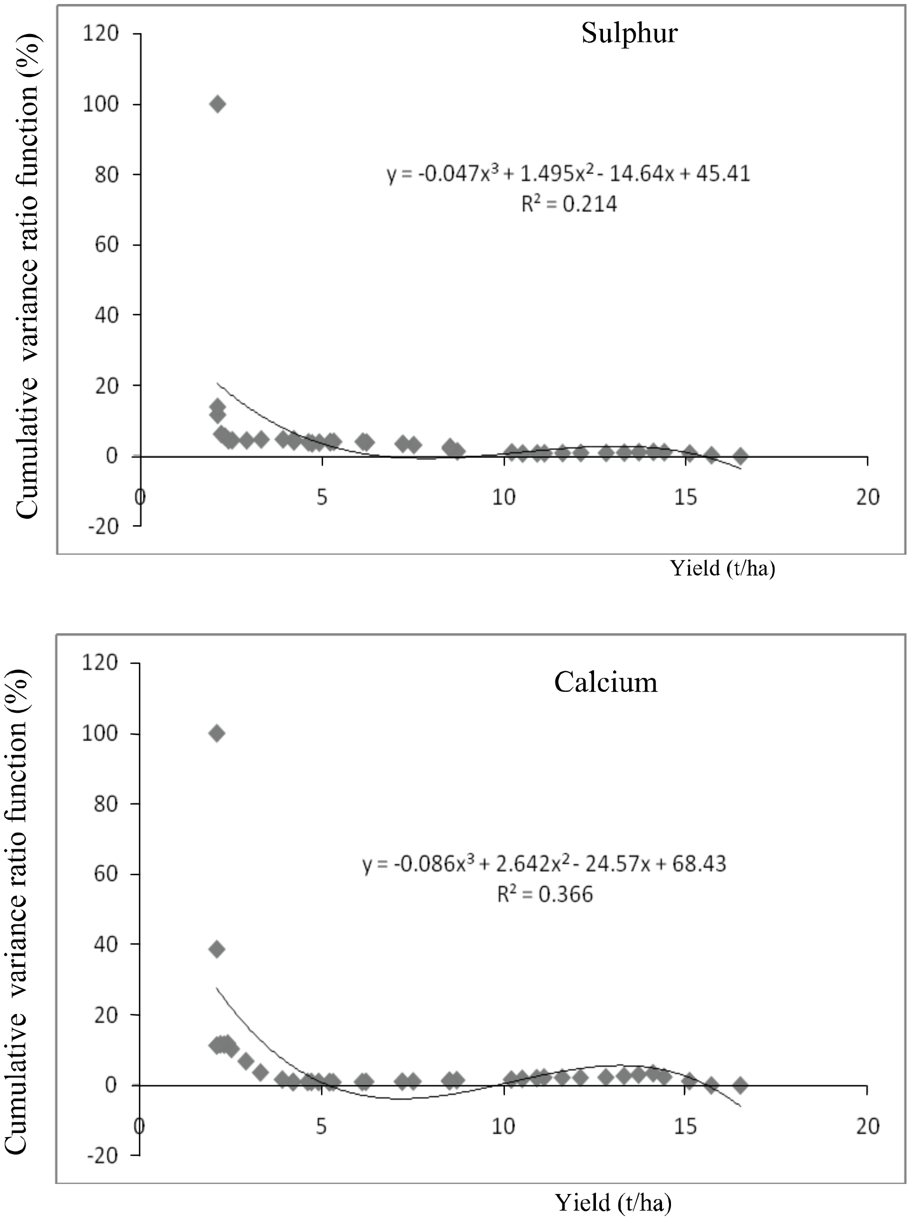

Fig. 2. Relationship between bulb yield of onion (BARI Piaz-1) and cumulative variance ratio function in S and Ca in farmers' field (n=42).

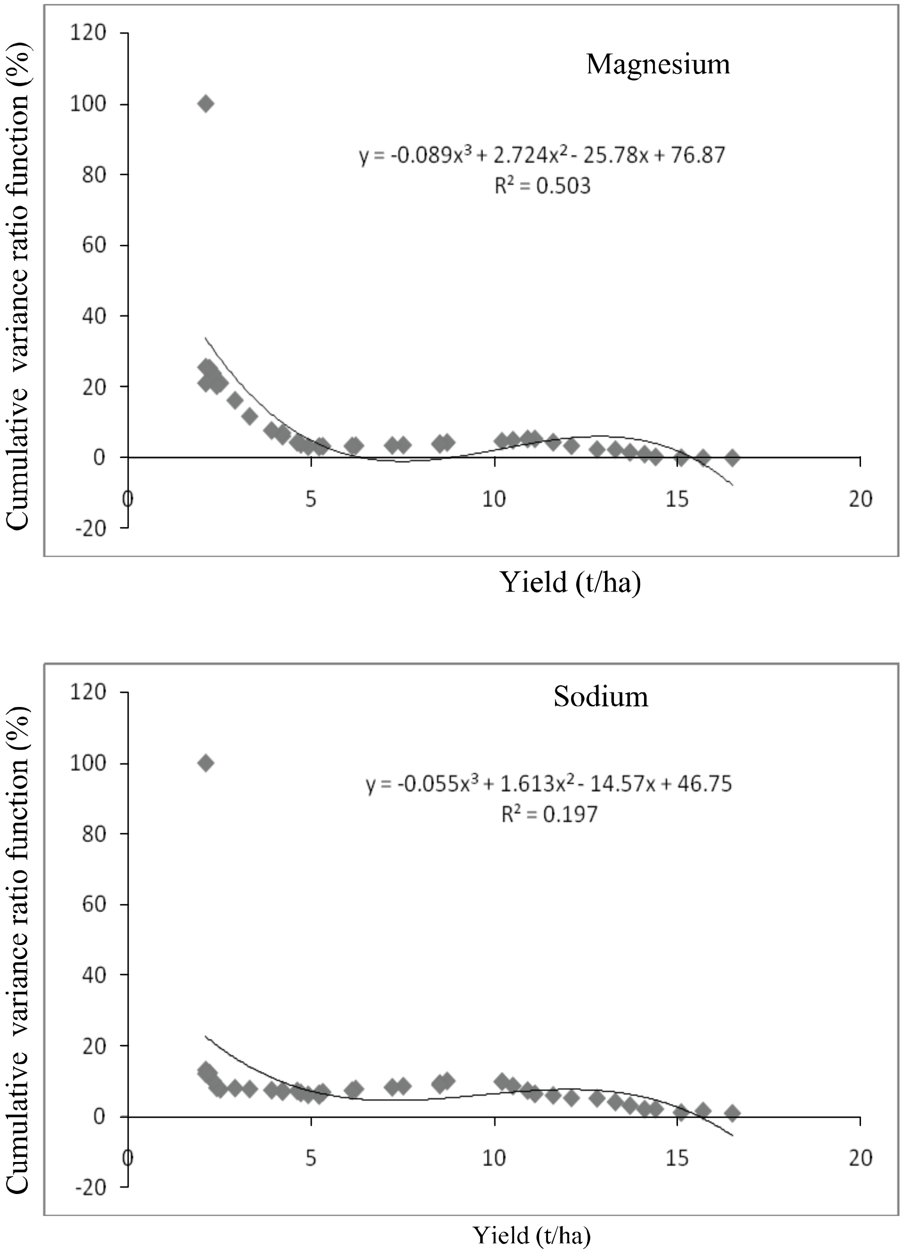

Fig. 3. Relationship between bulb yield of onion (BARI Piaz-1) and cumulative variance ratio function in Mg and Na in farmers' field (n=42).

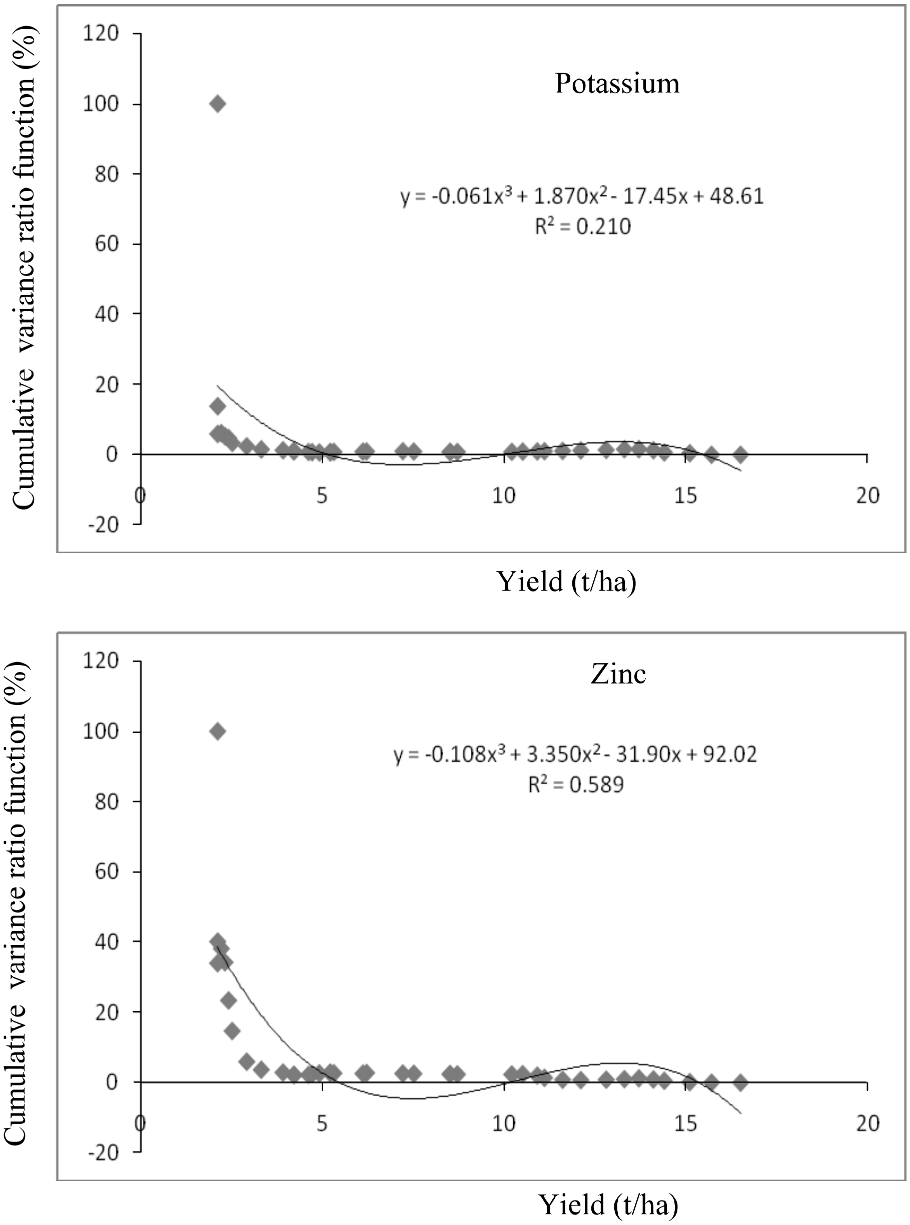

Fig. 4. Relationship between bulb yield of onion (BARI Piaz-1) and cumulative variance ratio function in K and Zn in farmers' field (n=42).

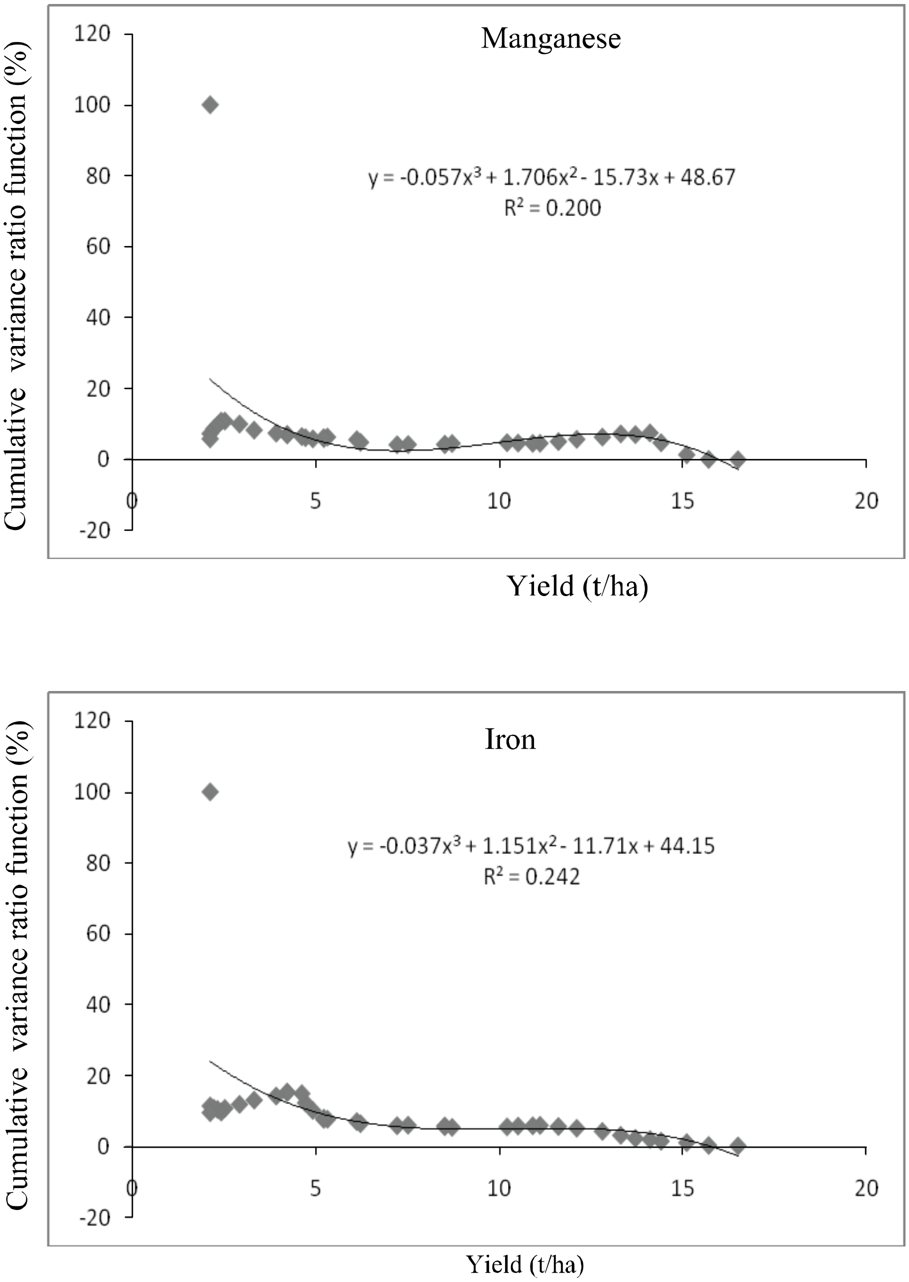

Fig. 5. Relationship between bulb yield of onion (BARI Piaz-1) and cumulative variance ratio function in Mn and Fe in farmers' field (n=42).

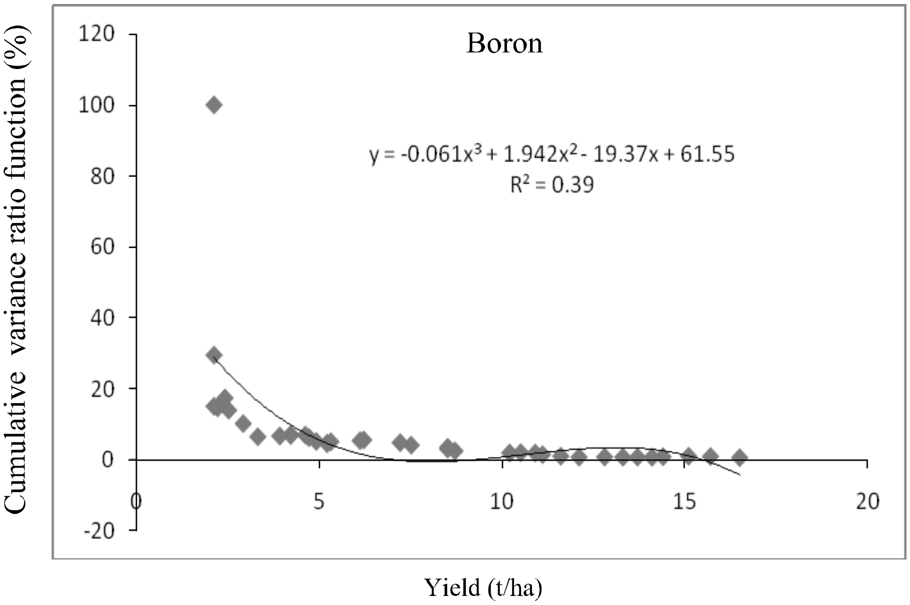

Fig. 6. Relationship between bulb yield of onion (BARI Piaz-1) and cumulative variance ratio function in B in farmers' field (n=42).

Table 1. Bulb yield of onion at Inflection points of Cumulative Variance Functions for Row-Centered Log Ratios [$F^c_i(V_x)$] in the Survey Population (n=42).

Nutrient	$F^c_i(V_x) = aY^3+bY^2+cY+d$	R^2	Yield at inflection point $(-b/3a)$ (t/ha)
N	$-0.075x^3 + 2.356x^2 - 23.41x + 76.82$	0.544	10.47
P	$-0.065x^3 + 2.032x^2 - 19.30x + 54.23$	0.270	10.42
S	$-0.047x^3 + 1.495x^2 - 14.64x + 45.41$	0.214	10.60
Ca	$-0.086x^3 + 2.642x^2 - 24.57x + 68.43$	0.366	10.24
Mg	$-0.089x^3 + 2.724x^2 - 25.78x + 76.87$	0.503	10.20
Na	$-0.055x^3 + 1.613x^2 - 14.57x + 46.75$	0.197	9.77
K	$-0.061x^3 + 1.870x^2 - 17.45x + 48.61$	0.210	10.22
Zn	$-0.108x^3 + 3.350x^2 - 31.90x + 92.02$	0.589	10.34
Mn	$-0.057x^3 + 1.706x^2 - 15.73x + 48.67$	0.200	9.98
Fe	$-0.037x^3 + 1.151x^2 - 11.71x + 44.15$	0.242	10.37
B	$-0.061x^3 + 1.942x^2 - 19.37x + 61.55$	0.390	10.61

Mg, Zn, Mn, Fe, and B deficiency. The high-yielding subpopulation had P, S, Ca, and K concentration slightly higher than the lower limit of sufficient range. Observed N, P, S, Ca, Mg, Zn, Mn, Fe, and B concentration in the onion plant in low-yielding subpopulations was deficient due to concentration was below the sufficient range. Beside these, the study area showed a prominent deficiency of micronutrients as it far more differ than the sufficiency level (Table 2). However, in onion plants in the study area contained high concentration of P, which was above the sufficiency level due to the soil of study area was acidic in nature. The nutrient concentration in both high and low-yielding subpopulation showed good symmetry. Skewness in the high and low yielding subpopulation varied from –1.62 to 0.49 for N, -0.60 to 0.38 for P, 0.28 to 0.13 for S, -0.4 to1.01 for Ca, -2.09 to 0.79 for Mg, 0.61 to 1.34 for Na, 1.79 to 0.24 for Zn, 2.20 tod 0.19 for Mn, 1.89 to 0.49 for Fe and 0.61 to 0.86 for B (Table 2). Dual ratio of nutrient (Table 3) shows that in the both high and low yielding subpopulations was 7.74 and 9.9091 for N/P, 0.96 and 0.966 for N/K, 7.53 and 8.831 for N/S, 2.59 and 2.550 for N/Ca, 21.73 and 29.650 for N/Mg,0.131 and 0.117 for P/K, 1.037 and 1.027 for P/S, 0.357 and 0.309 for P/Ca, 2.958 and 3.453 for P/Mg, 7.854 and 9.053 for K/S, 2.720 and 2.643 for K/Ca, 23.016 and 30.629 for K/Mg, 0.349 and 0.336 for S/Ca, 2.971 and 3.742 for S/Mg, 8.456 and 11.851 for Ca/Mg and 5.063 and 6.169 for Fe/Mn ratios. N/Ca, P/K, P/S, K/Ca and S/Ca ratios showed the greatest nutritional imbalance in the onion plant. Nutrient imbalance involving P or K

Table 2. Summary statistics for bulb yield and leaf nutrient concentration data for High yielding (n=5) and low yielding (n=37) subpopulations.

Crop parameter	High yielding subpopulations(n=5)					Low yielding subpopulations (n=37)				
	mean	median	min	max	skew	mean	median	min	max	Skew
Yield(t/ha)	15.16	15.1	14.1	16.5	0.42	6.19	5.2	2.1	13.7	0.59
N(g/kg)	40.22	41.2	31.5	45.2	-1.62	3.46	3.45	3.01	4.12	0.49
P(g/kg)	5.52	5.6	3.7	6.7	-0.60	0.42	0.4	0.2	0.68	0.38
S(g/kg)	5.42	5.4	4.5	6.5	0.28	0.46	0.44	0.21	0.77	0.13
Ca(g/kg)	15.52	16.2	13.9	16.9	-0.48	1.38	1.35	1.15	1.86	1.01
Mg(g/kg)	1.85	1.94	1.40	2.03	-2.09	0.15	0.14	0.03	0.35	0.79
Na(g/kg)	0.24	0.2	0.2	0.3	0.61	0.04	0.03	0.01	0.11	1.34
K(g/kg)	41.96	41.1	41.1	44.4	1.79	3.59	3.55	3.05	4.12	0.24
Zn(mg/kg)	0.03	0.036	0.015	0.036	-1.92	0.002	0.002	0.001	0.003	-0.58
Mn(mg/kg)	0.06	0.036	0.034	0.145	2.20	0.008	0.007	0.001	0.018	0.19
Fe(mg/kg)	0.24	0.2	0.2	0.35	1.89	0.03	0.028	0.02	0.049	0.49
B(mg/kg)	0.05	0.048	0.045	0.06	0.61	0.007	0.006	0.004	0.01	0.86

Table 3. Mean values of nutrient ratios for high and low yielding subpopulations together with their respective coefficient of variance (CV's), standard deviation (SD) and skewness.

Nutrient Ratio	High yielding subpopulations (n=5)				Low yielding subpopulations (n=37)			
	Mean	Skewness	SD	CV (%)	Mean	Skewness	SD	CV (%)
N/P	7.47	-0.064	1.080	14.46	9.091	0.881	3.023	33.26
N/K	0.96	-2.207	0.107	11.17	0.966	-0.181	0.066	6.88
N/S	7.53	0.0528	1.329	17.66	8.813	0.878	3.842	43.60
N/Ca	2.59	0.335	0.257	9.92	2.550	-0.350	0.368	14.46
N/Mg	21.73	0.643	0.601	2.76	29.650	2.641	20.096	67.78
P/K	0.131	-0.591	0.028	22.00	0.117	0.577	0.037	31.93
P/S	1.037	0.041	0.290	28.03	1.027	1.524	0.489	47.64
P/Ca	0.357	0.619	0.087	24.44	0.309	0.296	0.101	32.79
P/Mg	2.958	0.231	0.429	14.52	3.453	2.562	2.234	64.69
K/S	7.854	0.450	0.969	12.34	9.053	0.850	3.714	41.03
K/Ca	2.720	0.300	0.224	8.26	2.643	-0.783	0.362	13.72
K/Mg	23.016	2.205	3.554	15.44	30.629	2.565	20.258	66.14
S/Ca	0.349	-1.150	0.045	12.98	0.336	0.343	0.126	37.72
S/Mg	2.971	0.597	0.609	20.50	3.742	0.862	2.124	56.78
Ca/Mg	8.456	0.641	0.964	11.40	11.851	2.884	8.355	70.50
Fe/Mn	5.063	-2.174	1.489	29.42	6.169	2.175	5.969	96.75

deficiency in onion (Abbes *et al.*, 1995).With the inclusion of modern cultivation many soils of Bangladesh has become P and K deficient (Saleque *et al.*, 2009, Panaullah *et al.*, 2006 and Ali *et al.*, 1997). However, the slightly higher N/Ca, P/K, P/S, K/Ca, and S/Ca ratio in high yielding subpopulation than the low yielding subpopulation signifies that the imbalance due to Ca did not contribute much to the onion yield. The compositional nutrient diagnosis (CND) norms as row-centered log ratio (V_X) for N, P, K, Ca, Mg, S, Zn, Fe, and Mn are presented in Table 4. The high and low-yielding subpopulation had V_N 2.85 and 2.88, V_P 0.695 and 0.44, V_K 2.89 and 282, V_{Ca} 1.928 and 1.82, V_{Mg} – 0.394 and – 0.53, V_S 0.77 and 0.17, V_{Zn} – 4.41 and – 4.31, V_{Mn} – 3.36 and – 2.76, V_{Fe} – 1.87 and – 1.54 and V_B -3.37 and -3.44 . Difference in V_X was not large for any of the tested nutrient between high and low-yielding subpopulation.

Table 4. Compositional nutrient diagnosis (CND) row centered log ratio of nutrients with their mean and standard deviation

Row centered log ratio	High yielding subpopulation (n=5)		Low yielding subpopulation (n=37)	
	Mean	SD	Mean	SD
V_N	2.85	0.169	2.88	0.078
V_P	0.695	0.303	0.44	0.142
V_S	0.770	0.355	0.17	0.200
V_{Ca}	1.928	0.179	1.82	0.144
V_{Mg}	-0.394	0.394	-0.53	0.081
V_{Na}	-1.860	0.598	-1.76	0.255
V_K	2.89	0.164	2.82	0.124
V_{Zn}	-4.41	0.318	-4.31	0.256
V_{Mn}	-3.36	0.659	-2.76	0.540
V_{Fe}	-1.87	0.279	-1.54	0.171
V_B	-3.37	0.251	-3.44	0.089

Conclusion

Generic approach to select a minimum yield target for the high yield subpopulation was found effective for a small database of onion. B, S, N, P and Zn inadequacy was the major limiting nutrient factor for onion bulb production. B, S, N, P, and Zn nutrient dose for onion should be increased to improve bulb yield of onion in northern region of Bangladesh.

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