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BALANCED FERTILIZATION FOR BETTER CROPS IN VIET NAM

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"Balanced fertilization for better crops in Viet Nam [1]"

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1. Introduction

Vietnam is an agricultural country characterized by a small land base and a large population. (Presently the country ranks 58th in terms of area and 12th in terms of population among the nations of the world). During the second half of the 20th century, Vietnam's population tripled to presently nearly 80 million. Between 1980 and 1999 its cultivated area per caput decreased by 18,7 % and the per-caput rice area decreased by 47,7 %. Faced by such high population pressure, food security has become Vietnam's overriding political and economic goal. Supporting a large population on a small base of cultivable land has consequences for the environment. Overuse of land is thus seen as the underlying reason for widespread soil-fertility decline and for the expansion of degraded and eroded land areas in Vietnam.

In the past, crop production increase depended mainly on two factors: area and yield. Under conditions where a small land base limits expansion of crop area, as presently in Vietnam, yield increase becomes a major factor of potential productivity gains. It has been estimated that yield increase contributed over 80 % to increased cereal outputs during recent years and may reach up to 100 % in the near future (IFPRI, 1996). Apart from continuous introduction of new germplasm (higher yielding crop varieties), increase of farming and cropping intensity is seen as the main solution to achieve higher crop yields. As more harvests per unit area require more nutrients, fertilization and nutrient management plays an important role in crop productivity increase. This explains why Vietnam's agriculture has shifted from a traditional "soil based" to an intensified "fertilizer dependent" one.

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2. Fertilizer Production and Distribution

2.1 Organic Fertilizers

Vietnam has a long history in the use of organic fertilizers (approximately 1800 years). At present, organic fertilizers account for 25 % of total nutrients applied to crops. The commonly used organic fertilizers are farmyard manure, crop residues and green manure. In some areas, manure is used in the form of organo-mineral ("bio") fertilizers.

Farmyard manure (FYM): It has been calculated that, if all manure were collected from Vietnam's domestic animal population and processed, 11.7 t/ha of FYM (equal to 41.1 kg N, 20.5 kg P_2O_5 and 41.1 kg K_2O) could be supplied annually per ha cropland.

Crop residues: This is an important nutrient source. Based on the amounts of rice straw, maize stover, soybean leaves and stems of peanuts harvested at present in Vietnam, crop residues amount to 2,6 – 2,7 t/ha (equal to 14 kg N, 7 kg P_2O_5 and 34 kg K_2O). It is estimated that, in average, FYM and crop residues could provide 20-30 % N and P requirement and 60-70 % requirement of K for crops.

Green manure: In the past, *Azolla* and *Sesbania* were commonly used as green manure crops in lowland agriculture. Today these crops have virtually disappeared. Instead, farmers normally make use of food legumes in crop rotations and mixed cropping systems.

Based on a recent survey, it is calculated that FYM represents 65-75 %, green manure and crop residues 18-20 %, peat and mud 3-4 %, fermented waste 6-7 % and other organic materials around 4-5 % of the total amount of organic fertilizers presently in use in Vietnam.

2.2 Manufactured Fertilizers

2.2.1 Domestic Production:

1.1.1.1 Urea

At present, Vietnam has one urea factory with capacity of 110,000 t urea per year. However, during the years 1999 and 2000, only 50,000 t urea were produced as compared to 81,000 t during the first 10 months of 2001. A record production of 130,000 t urea was achieved in 1997 (Table 1).

Table 1 Domestic Urea Production ('000 t)

1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Jan-Oct. 2001
24	45	83	100	103	111	120	130	65	50	50	81

1.1.1.2 Phosphorous Fertilizers

There are presently four phosphate fertilizers manufacturing sites in Vietnam, two of which are single super phosphate (SSP) producers and two are thermo-phosphate (FMP) producers. During recent years Vietnam's total annual production of phosphate fertilizers amounted to around 1 Mt (Table 2).

Table 2 Domestic Phosphorous Fertilizer Production (SSP and FMP), ('000 t)

1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Jan-Oct. 2001
326	391	423	450	719	799	823	840	870	1050	1000	800

1.1.1.3 Mixed NPK Fertilizers

There are many production sites for of mixed NPK fertilizers representing a large number of nutrient combinations and formulas. Vietnam's total mixed fertilizer production amounts presently to approximately 1 M t with an estimated NPK nutrient content at a ratio of N: P_2O_5: K_2O = 5:10:3 (Table 3 and 4).

In total there are presently 1420 types of locally produced or imported fertilizers (mostly blends and mixes) approved for use in Vietnam (Table 4).

Table 3 Mixed NPK fertilizer production ('000 t)

1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Jan-Oct 2001
0	135	120	130	147	179	246	363	523	1000	1200	667

Table 4 Types and number of mixed fertilizer presently approved for use in Vietnam

Type of fertilizers	Number of blends
Mixed NPK fertilizers	722
NPK + micro elements	362
Organo-mineral fertilizers	79
Single fertilizers	17
Microbial fertilizers	20
Others (including foliar fertilizers)	220
Total	1,420

1.1.1.4 Imports of fertilizers

As the domestic production does not meet Vietnam's fertilizer demand, the country has to import large quantities of fertilizers. Imported urea increased from 956,000 t in 1990 to 1,950,000 t in 2000. All potassium fertilizers are imported.

Table 5 Imported fertilizers ('000 t)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Jan-Oct 2001
Urea	956	1322	1040	1049	1329	1268	1586	1522	1941	1900	2108	1100
AS	na	na	na	na	na	na	na	na	na	na	436	230
DAP	0	130	193	124	186	300	458	276	300	545	400	330
NPK	0	65	95	51	220	310	351	372	411	134	200	130
KCl	41	13	55	22	84	105	184	200	344	712	637	400

Source: MARD,10/2001, VN Economic News 6/2001 (General Custom Office)

1.1.1.5 Fertilizer use

Vietnam's recent agricultural development is dominated by intensification in the food crop sector. During the course of the last 40 years, the planted area of food crops increased by about 40 %, but food crop production increased by 247 %. Modern germplasm and fertilizer use are seen as the key factors of this remarkable development. Research results indicate that contribution of mineral fertilizers and FYM to total food production was 33-35 % and 5-6 %, respectively. The remaining increase in food productivity is based on the use of improved crop varieties, better irrigation, the application of integrated pest management (IPM) and natural soil fertility.

Table 6 Area, Yield and Production of food crops 1930-2000

Year	Cultivated area		Planted area		Production (in rice equivalent)	
	'000 ha	% as 1960	'000 ha	% as 1975	'000 t	% as 1960
1930	4,509	89.4	-	-	5,480	55
1960	5,042	100.0	-	-	9,879	100
1975	5,578	110.6	6,192	100.0	13,493	136
1985	5,542	109.9	6,833	110.4	18,200	184
1990	5,225	103.6	7,111	114.8	21,408	217
1995	5,403	107.2	7,971	128.7	27,571	279
2000	5,800	128.6	9,060	146.3	34,259	347

Source: General Custom Office; Dao The Tuan. 1996 and MARD

During the course of this rapid development the level of fertilizer use per unit of land increased significantly. The average quantity of $N+P_2O_5+K_2O$ applied per one ha planted area nearly tripled from 58.7 kg to 170.4 kg during the last decade. At the same time the ratio of $N : P_2O_5 : K_2O$ improved from 100:12:5 in 1990 to 100:44:37 in 2000 (Table 7).

Table 7 Fertilizer consumption by year

Year	N	P_2O_5	K_20	Planted area	$N+ P_2O_5 +K_20$	Ratio
		'000 t		'000 ha	kg/ha	$N: P_2O_5 : K_20$
1990	452	55	24	9,040	58.7	1 : 0.12 : 0.05
1991	670	150	17	9,409	88.9	1 : 0.22: 0.025
1992	573	188	44	9,752	82.5	1 : 0.33: 0.076
1993	566	155	21	9,979	74.3	1 : 0.27: 0.037
1994	737	258	72	10,172	104.9	1 : 0.35: 0.098
1995	748	342	93	10,497	117.7	1 : 0.46: 0.124
1996	937	432	146	10,929	138.6	1 : 0.46: 0.156
1997	889	366	150	11,316	124.2	1 : 0.41: 0.169
1998	1070	404	245	11,730	146.5	1 : 0.38: 0.229
1999	1068	515	467	12,320	166.4	1 : 0.48: 0.437
2000	1158	506	433	12,278	170.8	1 : 0.44: 0.374

Source: MARD

3. Balanced Fertilization for better crops in Vietnam

Vietnam has to import 90-93 % of her demand of nitrogen fertilizers, 30-35 % of phosphorus fertilizers and 100 % of potassium fertilizers. However, efficiency of fertilizer use is estimated to be only at 35-45 % for nitrogen fertilizers and 50-60 % for phosphorus and potassium fertilizers. This is explained mainly with farmers' lack of knowledge in the proper use of fertilizers. One of the key measures to improve fertilizer use efficiency is seen in balanced fertilization. In Vietnam, balanced fertilization is quite a new concept, which has been used widely only since its introduction through the IFA sponsored program on "Balanced Fertilization for Better Crops in Vietnam" (BALCROP), which is executed, by Vietnamese farmers, extension workers and scientists in co-operation with PPI-PPIC and IPI.

In principle the concept of balanced fertilization or balanced crop nutrition aims at a dynamic balance between nutrient requirement and uptake by crops. At the same time it seeks to maintain a balance between nutrients at different growth stages and at a balance between fertilizer nutrient supply and natural nutrient pools and conditions relevant to the effectiveness of fertilizer nutrient uptake (e.g. soil properties, water regimes and weather condition, etc.). The concept also aims to improve the balance of nutrient use by crops in crop rotations and farming systems.

4. Balanced fertilization for crops in relationship with soil characteristics

In Vietnam, there are 54 soil types belonging to 19 soil groups. A majority of these soils is characterized by nutrient contents, which are insufficient to sustain high yield levels. In addition, large soilscapes are affected by yield limiting factors such as high soil acidity, aluminum toxicity, salinization and a high level of alkalinity.

Many soils in Vietnam are characterized by small contents of plant available N, P, and K With the exception of soils originating from basalt, limestone and the alluvial soils of the Red River and Mekong River, which usually have larger contents of soil nitrogen, phosphorus (0.1-0.2 %), and potassium (1.5-2 %), many types of soils were found to have small reserves of total nitrogen (< 0.1 %), total phosphorus (0.03-0.06 %) and total potassium (0.3-0.5 %).

In terms of nutrient deficiency, nitrogen, phosphorus and potassium contents in Vietnamese soils are most relevant. As crops require these nutrients usually in largest quantity, their availability in soils affects the need for fertilizer nutrient supply most strongly. In areas with acid soils, calcium and magnesium deficiency is of relevance to the choice of fertilizer materials. Sulfur (S) and zinc (Zn) deficiency, which occurs in some soils of Vietnam, requires adequate supply of these nutrients from fertilizer sources. For example sulphur is not supplied where urea, DAP and MOP are used as sole fertilizer nutrient sources.

In general > 50 % of cultivated soils in Vietnam were found to have low nutrient contents and limiting factors that need to be overcome. Recent research results showed that 48 % of soil samples analyzed are deficient in Mg, 72 % in Ca, 80 % in K and 87 % in P.

There are many reasons given for the widespread soil fertility decline such as erosion, soil nutrient leaching and nutrient export in crop produce and crop residues not returned to the soil. In addition, there has been an increase of nutrient uptake with crops due to rising land use intensity and the increasing use of modern (high-yielding) varieties.

Imbalance in fertilizer use, especially excessive use of fertilizer nitrogen as compared to other fertilizer nutrients has caused increasingly mobilization and uptake of other nutrients from the soil reserves ("soil mining") during the course of rapid intensification of agricultural land use in recent years.

At the beginning of Vietnam's phase of rapid intensification of croplands around 1990 nitrogen was deficient in all kind of soils in Vietnam. Thus fertilizer nitrogen application caused remarkable yield response almost everywhere. However, the resulting imbalance in fertilization between nitrogen and other nutrients has increasingly exploited soil nutrient reserves since then. Results from research at the International Rice Research Institute in the Philippines revealed that, while an application rate of 174 kg N ha^{-1} increased rice yield by 2.9 times, it also caused the increase of P, K and S uptake by 2.6, 3.7 and 4.6 times, respectively (Table 8). Similar results were found in various studies in Vietnam. On acid soils for example, crop uptake of N was only increased by 40-50 kg N

ha^{-1} in the case of no additional phosphorus application. Nitrogen uptake increased however to 120-130 Kg N ha^{-1} where phosphorus fertilizers were applied. Similarly, it was found that potassium application enhanced N uptake on degraded soils in Vietnam.

Table 8 Nutrient uptake by rice (De Datta, 1995)

Nutrients	Parameters	Uptake (kg/ha/year)		
		1975-1980	1981-1990	1991-1993
N	Uptake	30.7	46.4	50.1
	Increased as 75-80 period, %	-	51.1	63.2
P_2O_5	Uptake	12.2	18.7	19.9
	Increased as 75-80 period, %	-	53.3	63.1
K_2O	Uptake	33.6	50.8	52.9
	Increased as 75-80 period, %	-	51.2	57.4

Source: Nguyen Vy. 1995

Before the 1990's, potassium fertilizers were hardly used by farmers in Vietnam a major reason being a high content of potassium (1.2 - 2.1 % K) in most paddy soils and the use of traditional rice varieties with rather small requirements for nutrients due to a smaller yield potential. A generally lower level of nitrogen application and the common use of large amounts of FYM as a source of K supply were additional reasons for sufficient K uptake by rice at that time.

Research has shown that the level of potassium content in the soil is the determining factor for potassium efficiency. It was found that on alluvial soils in Vietnam fertilizer K use efficiency is only at the rate of 1-2.5 kg paddy rice per applied kg K_2O. However, fertilizer K use efficiency on grey degraded soils or sandy soils was found to be 5 –12 kg paddy per kg of applied K_2O. Rice varieties also have affected the potassium effectiveness.

5. Balanced fertilization for crops in relationship with organic fertilizers

With regard to the nutrient supply balance for crops the relationship between mineral and organic fertilizers as nutrient sources is of relevance. As the use of mineral fertilizers in this respect has increased dramatically in recent years in Vietnam the importance of organic fertilizers as a nutrient source for crops has declined. In principal it is expected, that organic fertilizer use supports soil fertility maintenance and creates a base for intensive farming by improving chemical fertilizer effectiveness.

In most soil types of Vietnam, FYM application increased fertilizer nitrogen effectiveness significantly. Rice yields for example, are largest when the nitrogen rate supplied in manure is about 30 % of total N application. However, nitrogen supply from manure should not be > 40 % of the total, although effectiveness of N in FYM was found to be larger than in mineral fertilizers (20-22 kg paddy per kg N in FYM as compared to 10 -14 kg in mineral N fertilizer).

A good balance between organic and inorganic nutrient sources increases the effectiveness of mineral fertilizers, and vice versa. When mineral fertilizer is applied the response to 1 ton of FYM applied is 53-89 kg paddy rice, while it is only 32-52 kg without mineral fertilizer application (Table 9). In coffee, an increased FYM application decreased the amount nitrogen needed to produce 1 tonne of coffee beans and thus increased nitrogen use efficiency (Table10).

Table 9 Relationship between organic and inorganic fertilizers for rice

Land type	Fertilizer application	Effectiveness (kg paddy / 1 tonne FYM)
Alluvial soils	With mineral fertilizers	52
	Without mineral fertilizers	89
Degraded soils	With mineral fertilizers	32
	Without mineral fertilizers	53

Table 10 Effect of organic fertilizers on nitrogen *efficiency for Robusta coffee*

FYM (t/ha)	N Amount needed to produce 1 tonne of bean (kg)	N fertilizer use index (%)
0	24.9	37.2
5	19.6	44.6
10	17.0	52.8

Source: Trinh Cong Tu. 1997. N-rate: 200 kg N /ha.

Organic fertilizers were found to have a large effect on the efficiency of potassium fertilizers. If 10 t FYM ha^{-1} (1 tonne of FYM provides 2.5-3.0 kg K_2O) are applied, paddy yields of 5 - 5.5 t ha^{-1} can be achieved without additional potassium fertilizer application on soils with a total potassium content between 1.5 and 2.0 %. Thus on a number of soils which derived from alluvial sediments only a small quantity of additional fertilizer K is required to sustain larger yields. In soils with small K contents, FYM application was found to provide 40 % of potassium requirement in rice.

When compared with irrigated rice the role of organic fertilizers was found to be quite different in rain-fed cropping systems. A typical example with regard to the balance between nutrient supply from organic and inorganic sources is given for maize. Here organic fertilizers are not only a source of nutrients, but also contribute significantly in improving soil physical characteristics. However, without mineral fertilizer application (especially fertilizer nitrogen), the effectiveness of FYM is quite low. For example in the case of sole FYM application, the response is only 30 kg of maize grain per ton of manure. If FYM application is combined with fertilizer nitrogen application, this response is increased to 126 kg of grain per t FYM.

Since a majority of upland soils in Vietnam have a large phosphate sorption capacity, organic fertilizers can be used to reduce P fixation in such soils. The use of FYM or crop residues or green manure improves effectiveness of both organic and inorganic fertilizers significantly in this respect.

Soil characteristics also determine the time of fertilizer application. On light textured soils with a low cation exchange capacity (CEC), it is necessary to split fertilizer application, especially for fertilizer nitrogen and potassium as these are easily leached on such soils. Phosphorus fertilizers are commonly applied in one basal rate but on acid soils (especially acid sulphate soils) this rate should be split into two.

Organic fertilizers are important in maintaining the nutrient supply balance for crops and contributing to improving and maintaining soil fertility. Recently, organic farming has been encouraged as an alternative agriculture, which provides an optimum nutrient balance solution for both, large sustainable crop yields and a safe environment. In fact, it has been proved that organic fertilizers can only be an additional source of nutrients as well as a factor for improving soil physico-chemical conditions, but can not completely replace mineral fertilizers under conditions of increasing cropping intensity and increasing productivity as presently met with in Vietnam.

6. Balanced fertilization for crops in relationship to crops and varieties

Balanced fertilization implies also that nutrient requirement of crops and even varieties are satisfied as much as possible. Crops can differ substantially with regard to their nutrient requirement. Also, the ability of nutrient uptake by crops differs in relation to different soils and fertilizer materials. Thus when applying the principles of balanced fertilization to different cropping patterns, it is important to balance nutrient requirement and supply for the whole cropping system and to take into account residual effects of previous crops in this respect.

Modern (high yielding) varieties are known to require much more nutrients from soils and fertilizers than traditional (low yielding) varieties. Results from research indicate that traditional rice varieties in Vietnam such as Chiem chanh, Chiem bau and Ba trang take up only 18-20 kg N ha^{-1} and 7-8 kg P_2O_5 ha^{-1}, representing about 10-15% of the amounts of N and P taken up by improved varieties.

Similarly, hybrid rice was found to take up much larger quantities of K per crop than improved varieties of rice (Table 11). Hence, as a consequence of the countrywide introduction of modern crop varieties the total uptake of nutrients per ha increased rapidly over the last 20 years in Vietnam.

Table 11 Rice varieties and their nutrient uptake

Variety	Yield	Uptake. kg/ha		
	t/ha	N	P_2O_5	K_2O
Chiem chanh	1.40	25.2	4.2	
Chiem bau	1.13	19.3	3.0	
Ba trang	0.86	14.6	2.5	
Mè	1.07	16.8	3.3	
Improved rice	5.0-5.5	100 - 120	40 - 50	100 - 120
Hybrid rice	6.5-7.0	150 - 180	70 - 80	180 - 200

Source: Project 02A-06-01

Groundnut, a calcophil crop requires Ca in larger amount. Thus, on degraded soils with low contents of Ca and Mg, lime application and magnesium application increased groundnut yield by 9 –10 % and 11 % respectively. Besides supplying Ca as a nutrient, lime also reduces soil acidity and improves the soil environment for legumes with regard to biological N fixation. However, excess use of lime decreases groundnut yield due to an over-representation (imbalance) of calcium on the surface of cation exchangers in the soil.

7. Balanced fertilization for crops in relation with other nutrients

Before the 1960's, the use of fertilizers by Vietnamese farmers was not common as most of them grew only one crop per year using traditional varieties with low productivity. These crops required relatively small amounts of nutrient (Table 11). Since 1960, farmers started using manufactured fertilizers and most of that were imported nitrogen fertilizers (mainly ammonium sulphate -AS). Although only small amounts of fertilizers were applied at that time, the use of fertilizers induced a rapid agricultural production increase in Vietnam, particularly in rice production. During that period of fertilizer introduction to Vietnam, fertilizer nitrogen was the over-riding yield limiting factor in all kind of crops. Phosphorus fertilizers either imported or locally produced were hardly used for yield improvement by farmers during that period.

Results from research studies conducted during the 1970's indicate that fertilizer P (due to an increasing intensification of land) had become the second yield limiting nutrient factor after fertilizer N in Vietnam. Only in the 1980's, after modern rice varieties had been introduced widely in Vietnam, fertilizer K became the third yield limiting nutrient factor. Fertilizer K nutrient response became particularly prominent on light textured soils with small potassium reserves. This was even more so in the 1990's when improved planting materials had also entered other crop sectors and hybrid varieties were grown by rice and maize farmers more commonly.

7.1 *N-P balance*

As mentioned before, in the 1960's, nitrogen was the most limiting nutrient factor to crop yield but during the 1970's and the 1980's phosphorus replaced nitrogen in this respect. The use of modern varieties, an increased number of crops per year and an excessive use of nitrogen were main reasons to increased phosphorus fertilizer use efficiency (Table 12).

Table 12 Balanced fertilization and rice yield on acid sulphate soils

Treatment	Yield (t/ha)	N needed to produce 1 kg of paddy
Without fertilizers	0.38	-
60N	1.85	40.8
60N+60P_2O_5	3.37	20

Source: Project 02A-06-01. 1990

The studies showed that on alluvial soils or slightly acid soils, fertilizer nitrogen is most efficient if applied in balance with fertilizer P. Where Fertilizer N is used alone, a much larger application of fertilizer N is required per kg paddy yield than in cases where fertilizer N and P are applied together (Table 13).

Table 13 Relationship between potassium and nitrogen

Type of soils	N needed to produce 1 kg of paddy	
	Without P- application	With P- application
Red River alluvium soils	23-27	19-23
Cuu long River alluvium soil	18-20	16-18
Acid sulphate soil of the North	34-36	26-28
Acid sulphate soil of the South	30-34	17-20

Source: Project 02A-06-01. 1990

Nutrient interactions are another issue to be considered in balanced fertilization. Research results obtained on Red River alluvial soils for winter maize showed that efficiency was small, if nitrogen was applied alone. In this case fertilizer profitability (at a value:cost ratio (VCR) of 1.98) was also small. When fertilizer N was applied together with fertilizer P, the VCR increased to 2.47 and when fertilizer K was applied in addition to P and K, the VCR was further increased to 2.8. Thus balanced fertilization increased yield response and profitability (Table 14).

7.2 N-K balance

The relation between N and K in crops is known to be of special importance and their interaction in crop productivity can be either antagonistic or synergistic. Because of this relationship, scientists view potassium as a major factor in adjusting nitrogen supply for crops.

Table 14 Balanced fertilization for maize on Red River alluvial soil

Treatments	Yield t/ha	Yield increase t/ha	Efficiency, kg of maize by kg of nutrient	VCR
No fertilizers	0.45	-	-	-
N	1.48	1.03	8.6	1.98
NP	2.80	2.35	11.2	2.47
K	0.45	0	0	0
NK	2.13	1.68	8.0	2.25
NPK	3.75	3.30	11.0	2.80

For many decades, Vietnamese rice farmers have used fertilizer K only in small amounts (or not at all) as many rice soils used to have relatively large total potassium contents and most farmers used traditional rice varieties (with small requirement for potassium). Therefore the role of potassium in rice productivity was not proven, except on light textured soils with small contents of soil K (e.g. degraded and sandy soils).

In the meantime response to fertilizer K increased significantly as K requirements of lowland cropping systems increased due to more intensive farming and the use of modern varieties for most crops. Recently it was found in an increasing number of cases on some soil types, that application of fertilizer N and P to rice results in similar yields as zero fertilization.

For example N and P fertilization increased paddy yield by 1.17 t/ha on alluvial soils but only 0.12 t/ha on degraded soils. Similar results were received also on alluvial soils in comparison to grey soils of the Southern Mekong River Delta (Table 15 and 16).

Table 15 Efficiency of nitrogen and potassium balance for rice on soils rich in potassium, t/ha

Treatment	Red River alluvial soils		Cuu long river alluvial soils*	
	Yield	Yield increase	Yield	Yield increase
No fertilizers	3.35	-	-	-
NP	4.52	-	4.09	-
NPK	4.75	0.23	4.54	0.45

** Source: Do Trung Binh. 1995*

Table 16 Efficiency of nitrogen and potassium balance for rice on soils poor in potassium

	Degraded soils		Grey soils*	
	Yield, t/ha	Yield increase	Yield, t/ha	Yield increase
No fertilizers	2.15	-	-	-
NP	2.27	-	2.89	-
NPK	3.32	1.05	4.09	1.20

** Source: Do Trung Binh. 1995*

When fertilizer K was added to the fertilizer N and P combination the resulting yield response indicated, that fertilizer K use efficiency is related strongly the indigenous K supply capacity (the soil potassium content). In soils rich in potassium such as the alluvial soils, fertilizer K use efficiency is only 2-4 kg of rice per kg K_2O while it can reach 8-13 kg of paddy per kg K_2O on degraded and sandy soils (Table 15 and 16).

The role of N-K balance becomes more important where larger rates of fertilizer N are applied. Relevant studies on alluvial soils showed that if N supply was below 120 kg fertilizer N per ha and 10 t of FYM ha^{-1} fertilizer K use efficiency was found to be small. However, where N supply is increased above 150 kg N ha^{-1} fertilizer K efficiency becomes large. This is even more so on degraded soils. Under such conditions Fertilizer K application clearly increases N use efficiency in rice.

Without K application, N use efficiency is usually 15-30 %, but it reaches 39-49 % when applied together with fertilizer potassium. Thus potassium plays an important role in regulating nitrogen supply and can assist in improving uptake of nitrogen and other nutrients in rice and other crops (Table 18 and 21).

Table 17 Effect of potassium on Nitrogen effectiveness to rice on degraded soils (Kg paddy rice/kg N)

Season	Without potassium	With potassium
Spring crop	8.1	13.2
Summer crop	2.1	4.7

Table 18 N-K balance for rice (Hybrid rice)

Rate of N kg/ha	Alluvial soil			Degraded soils		
	Yield		Yield increase due to K application	Yield		Yield increase due to K application
	Without K	With K		Without K	With K	
	t/ha					
0	4.72	4.63	-0.09	3.14	3.41	0.27
60	5.10	5.05	-0.05	3.65	4.60	0.95
90	5.41	5.55	0.14	3.88	5.24	1.36
120	5.87	6.09	0.22	4.21	6.03	1.82
150	6.43	6.82	0.39	3.92	6.15	2.23
180	6.37	6.87	0.50	3.51	5.59	2.08
210	5.42	6.37	0.95	3.01	4.63	1.62

It was also found that the N-K balance might be affected by seasonal factors. Recent studies revealed that during the summer season, which is characterized by comparatively higher temperature, crops will uptake more K from soils than in other seasons. Accordingly, fertilizer K use efficiency is smaller (Table 17). During the winter season (mostly in the North) with lower temperature and lack of sunlight, Fertilizer K use efficiency is higher. Thus generally larger quantities of fertilizer K should be applied to winter crops in Northern Vietnam.

Results obtained from studies in maize indicate that balanced N-K fertilization is comparatively more efficient in maize than in rice. Yield increase due to balanced fertilization could reach 3.3 t/ha on alluvial soils; 3.77 t/ha on degraded soils; 1.17 t/ha on grey soils and 0.39 t/ha on ferralitic soils in terms of maize grain. Balanced fertilization for maize on degraded and grey soils was found to be more profitable than on alluvial and ferralitic soils (Table 19 and 20).

Table 19 Maize yield in relationship of N-K balance *(t/ha)*

Treatment	Alluvial soils	Degraded soils*	Grey soils**	Ferralitic soils
No fertilizer	0.45	0.44		
NP	2.80	0.45	2.47	5.13
NPK	3.75	4.21	3.64	5.52

Source: Cong Thi Yen. 1995; Do Trung Binh. 1995

7.3 *Macro and secondary nutrient balance*

The rapidly increasing use of fertilizer N, P and K nutrients in cultivated areas of Vietnam has also increased the requirement for secondary and micro-nutrients. A major reason for this development is seen in the use of predominantly single fertilizer nutrient sources in Vietnam. For example the continuous use of urea, DAP and MOP was found to induce sulfur deficiency. In other cases the preferred use of DAP and SSP over FMP induced Mg deficiency. Thus NPK nutrient supply from the addition of fertilizers with large nutrient contents such as urea, DAP and MOP has not always caused the most significant effects as it also caused insufficient supply of other nutrients.

Table 20 Effectiveness of balanced fertilization for maize

Treatment	Kg maize produced by 1 kg of nutrient		VCR	
	Alluvium soil	Discolored soil	Alluvial soil	Degraded soil
NP	11.2	0.05	2.47	0
NPK	11.0	12.6	2.80	3.20

Table 21 N - K balance at different rate of nitrogen on Red River alluvial soils

Rate of N, kg/ha	0	45	90	135	180	225	270
Yield increase due to K application, ton/ha	-2.9	2.6	3.4	3.5	4.9	9.7	15.8

Table 22 Macro and secondary nutrients balance for peanut on degraded soils

Treatments	Yield, t/ha	%
NP	1.34	100
NPCa	1.46	109
NPK	1.50	112
NPKCa	1.65	123

Source: Nguyen Thi Hien. 1995

Research results indicate its is known that the use of fertilizers containing secondary and minor nutrients benefits crop performance when compared with single nutrient fertilizers. Studies comparing the efficiency of urea and AS or DAP, SSP, and FMP for example have proven this aspect of fertilizer use. Fertilizer N application provided at a rate of 30 % as AS and 70 % as urea for example increased coffee yield by 8-16 %. Similar results were obtained in research on efficiency of AS for maize and peanut. The yield increase in these cases is explained as response to fertilizer S, which is supplied together with N in AS. (Table 23).

Table 23 Nitrogen forms in nutrient balance for Robusta coffee

Treatments	Fresh nursery yield, t/ha	Yield increase, t/ha
200 kg N (Urea)	11.1	-
200 kg N (AS)	12.0	0.9
100 kg N (Urea)+100 kg N (AS)	12.9	1.8

Source: Luong Duc Loan. 1995

Combined SSP and FMP fertilization usually benefits crop performance on upland soils in Vietnam. A more gradual release of P from these sources and the beneficial effect of other nutrients such as S, Ca, and Mg are seen as reasons. The alkaline character of FMP not only balances the acidic character of SSP, but may also cause a liming effect on acidic upland soils and thus reduces the P fixation potential of these soils. In alkaline soils, combined FMP and SSP fertilization increases solubility of phosphorus in FMP. At the same time, the high Si content of FMP supports the formation of Al^{3+} compound, which can reduce alkaline toxicity. Consequently the combined application of SSP and FMP results in yield increase in acid as well as alkaline soils. Compared with FMP, combined SSP and FMP fertilization resulted in a yield increase of 0.37 t paddy ha^{-1} (9.2 %). When compared with SSP, the increase was 0.24 t of paddy ha^{-1} (5.8 %). In groundnut, combined SSP-FMP fertilization increased yield by 0.19 t ha^{-1} (10.3 %) when compared with separate application of FMP and SSP.

Due to insights gained during the course of the co-operative project on "Balanced Fertilization for Better Crops in Vietnam" (BALCROP) the principles of balanced fertilization are more widely adapted in Vietnam's agriculture of today than in the past. Improvement is not only noticed with regard to the rates and ratio of fertilizer NPK consumption, but also with regard to fertilizer use in relation to soil characteristics (Table 24).

Table 24 Rate and ratios of fertilizers used for rice in the North Vietnam

Type of soils	Year under survey	Kg/ha			Ratio of
		N	P_2O_5	K_2O	N: P_2O_5: K_2O
Red River alluvial soils	1992	76.2	26.4	2.0	1: 0.35: 0.03
	1998	109.5	54.8	47.5	1: 0.50: 0.43
Thai binh River alluvial soils	1992	87.1	40.0	2.0	1: 0.46: 0.02
	1998	94.6	62.9	39.5	1: 0.66: 0.42
Grey-degraded soil	1992	69.5	36.6	13.0	1: 0.53: 0.19
	1998	95.7	36.6	69.0	1: 0.38: 0.72
Sandy soils in coastal areas	1992	79.7	39.3	14.0	1: 0.49: 0.18
	1998	83.6	37.3	44.6	1: 0.45: 0.53

8. Balanced fertilization for crops in relation with disease of crops

Besides its yield increasing effect, balanced fertilization usually improves disease resistance in crops. Larger fertilizer N nutrient application or delayed fertilizer application often delays the ripening process, which causes thinning of cell walls. Thus diseases can penetrate cells more easily and cause destruction.

Due to the antagonistic relationship of N and K in crop physiology, fertilizer K supply can speed up lignin formation and increase cell wall thickness and thus improves disease resistance. In rice, a more controlled release of N from applied FYM in relation to K supply from the same nutrient source was found to increase disease resistance.

Table 25 Effect of balanced fertilization on disease infection in rice

Location	Sheat blight				Bacterial leave blight			
	Disease percentage		Disease index		Disease percentage		Disease index	
	NP	NPK	NP	NPK	NP	NPK	NP	NPK
Quoc oai	21.0	14.1	5.3	3.3	22.0	11.0	8.2	4.7
Thanh oai	11.2	10.0	2.7	2.2	32.0	16.0	11.0	6.5
Ha Rong	18.0	12.1	5.2	2.8	28.0	11.0	8.4	4.5

Source: Nguyen Tien Huy. 1995

Table 26 Balanced fertilization and disease infection in vegetables

Treatment	Head rot of cabbage, %	Bacterial wilt of tomato, %
NP	12	28.8
NPK	7	11.8

8.1 The roles of balanced fertilization

8.1.1 Stability and improvement of soil fertility

Research results proved that balanced fertilization could stabilize and improve soil fertility since exhaustive “nutrient mining” is avoided. Balanced fertilization not only compensates for nutrient uptake by crops, but also supports potential soil fertility build-up through increased crop residue recycling due to larger harvests of biomass on account of more balanced and sufficient nutrient supply. In sloping uplands, balanced fertilization limits soil erosion and soil degradation due to faster crop growth after planting and thus more protective vegetative cover on account of improved nutrient supply. Also, balanced fertilization supports stronger root systems, which may assist in improving soil physical conditions.

8.1.2 Increase of production efficiency.

With new varieties and advanced farming techniques, balanced fertilization helps not only to increase yields and improve product quality but also lowers cost of production and thus can increase the competitiveness of marketable agricultural produce.

8.1.3 Protection of water resources

Unbalanced and excessive use of fertilizers can harm the environment. There have been complaints that unprofessional use of N and P causes nitrate contamination in groundwater and the accumulation of nitrate and phosphate in surface near water bodies. However, pollution can be avoided where – in the true sense of balanced fertilization - organic and mineral fertilizer nutrient sources are applied rationally. This implies, that the right materials, forms, nutrient amounts and ratios are applied at intervals, in order to meet as exactly as possible actual nutrient requirement of crops in relation to soil nutrient contents at different growth stages. Any potential fertilizer nutrient losses are minimized under such conditions since crop uptake is more or less in balance with nutrient supply.

9. Conclusions

Balanced and adequate fertilization is a key to increase crop productivity and ensure sustainable agricultural production. Any country, either developed or developing, should use balanced fertilization as an important solution to increase agricultural productivity in a sustainable way. As in many developing countries, Vietnam's use of fertilizer nutrients is not well balanced at present and therefore causes misappropriation of revenues, land degradation and increasing pollution of the environment in addition to low quality agricultural produce. Vietnam is now in the process of industrialization and modernization. Agriculture needs to increase its quality to ensure national food security and to increase agricultural export values. In this process, balanced fertilization actively contributes to transferring agriculture from soil exploitative production systems to fertilizer supported knowledge based sustainable production and soil fertility building systems.

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