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MODELLING STRUCTURE AND FUNCTION OF AGRICULTURAL YIELD POTENTIAL

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ABSTRACT: The present paper theoretically examines the structural features and functions of crop-yield potential, which affect the crop-yield curve in a specific land environment. The magnitude of yield potential, which is based on the hidden capacity of land, rapidly declines in the initial phases of crop-yield. The most notable feature in yield potential system is that the biotic potential is exhausted with increasing strain on land environment to produce more yield specially in the later phases of crop-yield curve. The yield-rate curve is, consequently, the product of two rate factors: productive capacity of yield potential and potential resistance, which decline subject to intensification of yield-enhancing factors. Therefore, the present yield function follows the 'reciprocity law of crop yield increase' in which the optimal and suboptimal phases of yield increase are determined by equating the declining tendencies of crop-yield rate, absorption rate of yield potential and potential resistance (i.e., strain on land environment).

An empirical testing of the present model is presented in this paper considering a micro-areal level homogenous agro-ecological land condition of the Upper Brahmaputra plains of India (i.e., the Majuli river island of about 925 sq.km) where sufficient (paddy) crop-yield potential is available for further use. The optimal and sub-optimal conditions of the model confirm the facts that the application of HYVs of paddy seed has a greater scope for yield increase (B2=0.79272) compared to the application of chemical fertilizer (B1=0.52716).

INTRODUCTION

Introduction of technological factors, specially application of irrigation, fertilizer and seed technology in the process of agricultural crop-yield, is generally considered to have far greater impact on agricultural yield increase compared to its natural growth. It means that a plant gains comparatively better environmental conditions to its seed germination, growth and reproduction when suitable and required application of irrigation and fertilizer doses are given. However, it is universally realized that the increase in crop-yield follows the 'law of diminishing return' to the scale of technological intensification in the production processes operative in under-developed and developing agricultural conditions where adequate yield potential is available to use (Rao 1968, Hayami & Ruttan 1970). The diminishing return of yield factors may be the result of many and varied types of interactions which, consequently, alter the conditions of plant growth and also limit the environmental parameters of a piece of land.

From an ecological point of view, growth is essentially an interaction of two biological forces: (a) biotic potential which pushes the plant growth curve upward through the absorption of chemical components of environment and (b) environmental resistance which restricts its absorption rate and, consequently, checks the growth and stablilizes the yield increase (Chapman 1928, Kormondy 1996). The natural environment which generates crop-yield (biotic) potential has been altered by the 'created' environment with the help of (agricultural) technological factors. As a result, created environment modifies the conditions of yield potential and its absorption rate. However, yield potential is supported by the environment only upto a certain extent, a limit sometimes referred to as 'carrying capacity' of land environment by which the production function of a created environment is optimized (Kormandy 1996). It is realized that an objective production function within the set of attributes of production ecology is specified by tow concepts of farming system: productivity and efficiency. Productivity concept is based on the economic criterion of maximization of production with differing combinations of production factors. Efficiency concept follows a relative criterion to achieve a desired productivity by considering different levels of factors'interactions and agro-ecological conditions of the land. The efficient use of inputs under efficiency concept of the system can be considered in various ways: agronomically, ecologically as well as economically (Koeijer, et. al. 1999). However, the role of yield potential is always considered in optimizing the limit of production function and in measuring the efficiency of farming system in a specific land environment. In this context, there is a need to describe the structural and functional aspects of yield potential in order to optimize the yield function.

STRUCTURAL FEATURES

In the present context, the concept of agricultural yield potential is developed by comparing two main attributes of agricultural crop productivity: the maximum expected yield, A, and the Actual crop-yield, Y. A is wholly dependent on physical factors of land and is related to its total capacity. A number of criteria are considered while defining maximum expected yield level in the operation of arable farming systems. Infact, agronomic efficiency criterion of defining input -output combinations of farming systems for its self-sustained growth has been described in terms of 'resource-use efficiency' (De-Wit 1992). Under such criterion, three levels of production are considered on the basis of yield-enhancing factors, namely, production-generating, production-stablilizing and production-restricting factors. Physical factors of land related to climatic and soil conditions generate the yield potential and determine the potential production level (that is named here maximum expected yield). It is therefore merely dependent on total capacity of land environment (Rabbinge 1993, Van Ittersun and Rabbinge 1997, Koeijer, et.al. 1999). It has been assessed by various parametric methods by using plant growth models based on growth relationship and relevant land suitability factors (Vink 1975). For instance, soil and its fertility factors like its effective depth, saturation, available organic matter, salt content and soon are considered to optimize crop-yield for the assessment of the level of maximum genetic yield (Riquier 1972). Legumes are nitrogen fixation plants which maintain soil fertility and, consequently, improve the level of genetic yield potential in a healthy soil environment (Kahnt 1999). The agrometeorological factors of land are considered to assess the level of A by the meteorologists of the institute of Soil Science and Cultivation of Plants, Poland (Witek & Gorski 1977, Gorski & Spoz-Pac 1989, Gorski, et.al.1994). The priorities of soil fertility and agro-ecological factors of land are given by the scientists of Indian Council of Agriculture

Research, New Delhi for measuring the total capacity of land in terms of its level of maximum genetic or expected yield (Prasad 1987). Overall optimality and efficient use of land environment is merely related to the level of 'A' in agricultural farming systems.

On the other hand, the actual crop-yield, Y, is a result of various techno-economic and socio-cultural factors, which stabilize and/or alter the environmental conditions of land for the intensity of yield function (McCarty & Lindburg 1967, Wossink & Rossing 1998). Y is, therefore, related to the used capacity of land in terms of resource-use efficiency. The difference between total capacity and used capacity of land, which may be noted as hidden capacity, reflecting 'untapped yield gap' in the yield function, is defined here as the total magnitude of yield potential per unit of land, P:

$$P = (A-Y), \text{ s.t. } A>Y. \quad \text{------} \quad (1)$$

While its proportionate share to existing yield (Ps) is as

$$Ps = [(A-Y)/Y], \quad \text{------} \quad (2)$$

and its intensity (Ip) is defined as

$$Ip = [1+[(A-Y)/Y]] = A/Y. \text{-----} \quad (3)$$

The componental relationships and effective working of yield potential system take place when yield factors encounter the natural environment of land with the condition that there is enough availability of yield potential. Yield potential has capacity to absorb the environmental conditions to produce more yield. The maintenance of healthy conditions of natural environment through the application of yield -enhancing technology is the case of increasing reproductive forces through the generation and utilization of yield potential. In the initial stage of application of yield-enhancing factors, the physical environment of land is less influenced by them due to sufficient availability of yield potential and highter potential productivity. However, more environmental resistance is encountered by intensive application of yield-enhancing factors (X) because of lower carrying capacity of environmental attributes after certin limit of its effects. It is directly related to the agronomic efficiency of farming system ranging from zero to unity. Its degree can be expressed quantitatively by naming it as Potential resistance (Pr) which is defined as:

$$Pr = [(A-Y)/A], \text{ s.t. } 0 < Pr < 1. \quad \text{........} \quad (4)$$

where strain on land environment is inversely proportional to Pr. When Y is small, the value of potential resistance is more (near unity) with less strain on environment. In such conditions, there are numerous opportunities of reproduction of the yield by absorbing more yield potentioal intensity. But as Y appropaches towad A, the value of potential resistance comes close to zero with higher strain on environment. There are, consequently, fewer reproduction opportunities of crop-yield due to less availability of nutrients in the environment despite supplementing soil nutrients through created environment by yield-enhancing factors.

In fact, physical environment of land is changeable spatially as well as temporally. If land environment were altered by changing its chemical composition or through physical changes such as alteration in temperature and/or humidity conditions, the limit of carrying capacity of land potential (i.e., maximum expected yield level A in present case) would change accordingly.

Based on the above discussion, these structural components may broadly be classified into three groups as: (a) the yield potential components (related to its magnitude and intensity), (b) the existing yield and (c) the yield-enhancing factors that develop created environment to increase yield. Such triangular componential relationship is not simple but important to describe the structure of yield potential. As a result, structural features of yield potential phenomena are more complex and the functions are more complicated in its working.

YIELD-POTENTIAL FUNCTION

Triangular relationship of structural fratures is widely recognised by agricultural scientists and production economists with the conclusions that agricultural yield (or production) function follows the law of diminishing yield-rate to the intensity of yield factors (Spillman 1933, Rao 1968, Visser 1980, 1982). The growth and reproduction of a plant is recognised by following different laws of the supply of soil nutrients through the created environment. First, 'law of the minimum' is developed by Liebig considering a single but important element of soil fertility (i.e., phosphorus) for the growth of plants. A minimum quantity of phosphorous is required for plant growth (c.f. Heady & Dillon 1961, Kormondy 1996, 20-22). Later on, the interactions of other elements of soil fertility are also considered to assess the optimal levels of plant growth. A semi-logarithmic form of yield function was developed by Mitscherlich (1909) considering the maximum expected yield level as the upper limit of yield-function. However, the Shelford's 'law of tolerance' includes wide spectrum of factors for plant-growth related to both the geographical environment and ecological physiology of plant. The law is based on the distribution of plants species of a specific area, which is optimal only within a tolerance range of the interactions of its soil elements (Shelford 1911). Following such base of tolerance and optimal growth of plant, Spillman (1933) addressed an yield equation based on the 'exponential law' of yield increase under the specific conditions of maximum expected yield level, which, of course, depends on the available land environment as described earlier.

In such conditions of crop-yield increase, the growth strategy of a plant follows the McArthur and Wilson's (1967) criteria of logistic growth without its regulation factors. However, regulatory factors of growth and reproduction attributes stablilize the yield-increasing conditions on account of density-dependent influences (Chapman & Reiss 1992). they are:

(a) The limitation of space and self-thinning processes of plant growth, which follow a negatively curvelinear relationship between the plant -density and plant-mass (White 1980). It means that higher the plant density in specific piece of land, lesser is the plant-mass because of lesser supply of soil moisture.

(b) The limited food and water supply to plant growth, which restrict the survival, growth and reproduction of plants. It causes various deficiency disease in the plants, which affect the reproductive potential and stabilize the crop-yield increase; and

(c) The available limited land resources in the area of plant growth where carrying capacity of land environment is exhausted as plant growth takes place. However, a created environment of soils in the form of nutrient concentration specially at the root -zone space may alter 'the conditions of crop-yield increase and change the slope of yield curve. For example, potassium and magnesium are important yield-determining factors in the micro-environmental conditions of soils. The potassium supply rate increases plant yield while any displacement of magnesium by potassium in the plant's uptake gives rise to a reduction in the growth rate (Grimme, et.al 1977). Thus, growth and reproductive potentials are influenced by these environmental factors, which create variations in the structure of yield potential phenomena.

The variation in yield potential phenomena is determined here by speculating a specific kind of yield function Y(x) where the range of variation occurring in the total magnitude of yield potential per unit supply/application of yield -factor from its maximum level, A/X, to the minimum of {(A-Y)/X} is proportional to the total magnitude of yield potential as

$$(A-Y) = B\,[(A/X) - \{(A-Y)/X\}] \quad \ldots\ldots\ldots \quad (5)$$

where B is proportionality constant defining a product of proportionate share of yield potential with the unit of input application because $[\{(A-Y)/Y\} = BX^{-1} = Ps$. Since increasing use of X must diminish the proportionste share of yield potential, Ps, its product with X at each level of its application must be equal to B (Singh 1994). It means B shows the maximum response of yield attainable from the use of X. It defines the rate of transformation or reproduction at various levels of yield-factors. Therefore, it controls the absorption rate of yield pontential for its reproduction into yield function. Simplifications of the algebric form of Eqaution (5) for Y^{-1} and Y reproduce

$$Y^{-1} = A^{-1} + (B/A)\,x^{-1}, \quad \text{-----------} \quad (6)$$

and then

$$Y(x) = A\,[I+BX^{-1}]^{-1}, \quad \ldots\ldots\ldots\ldots\ldots \quad (7)$$

Subject to:

(i) X and Y are non -negative variables, and

(ii) A and B> 0 are constants.

There are three parameteres controlling the system of yield-potential and yield increase. The parametric relationships in the present function are described as the following:

(i) The parameter A has positive impact on the magnitude of yield potential. Higher value of A indicates favourafble environment and fertile soils and good conditions of sufficient available yield-potential for yield increase.

(ii) The parameter B is a major component of denominator of yield-function (eqn-7) which defines the intensity of yield potential because $(1.0+BX^{-1}) = Ip(x)$. The greater the value of B, the higher is the intensity of yield potential and vice-versa. The convexity of yield curve is controlled by this parameter as elaborated separately in the next section. Further, B controls the absorption rate of yield potential in the present equation. As X is intensified, it encounters intensity of yield potential, diminishes its proportionate share (i.e., Bx^{-1}) and transfers it into crop-yield. It means B defines absorption rate of yield-potential intensity and gives maximum response of reproduction in yield function attainable at different levels of X application. The higher the value of B, lesser is the convexity in yield curve and vice-versa (Fig. 1, Table 1).

(iii) The 'Unity-constant', which is attached with the denominator of yield function, does not affect Y in its intitial phase of input application. However, at later phases of intensification when X tends to infinity, Bx^{-1} becomes very small, then unity-constant controals yield curve to be parallel to A. Thus, an asymptotic divergence in yield curve may be seen specially in the later phases of production (Fig.1).

Table-1

Effect of Absorption Rate of Yield Potential Intensity (B) in Yield Function when A is constant at 1.75

Input Level (X)	Change in crop -yield (Y) at different B values as:				
	Y_1 (B=0.25)	Y_2(B =0.65)	Y_3= (B = 1.75)	Y_4 = (B = 2.25)	Y_5 (B = 5.25)
0.01	0.0673	0.0265	0.0099	0.0077	0.0033
0.25	0.8750	0.4862	0.2187	0.1750	0.0795
0.50	1.1666	0.7609	0.2889	0.3182	0.1522
0.75	1.3125	0.9375	0.3250	0.4375	0.2187
1.00	1.4000	1.0606	0.6364	0.5385	0.2800
2.00	1.5555	1.3207	0.9333	0.8235	0.4827
3.00	1.6154	1.4383	1.1053	1.0000	0.6364
4.00	1.6471	1.5053	1.2174	1.1200	0.7568
5.00	1.6666	1.5487	1.2963	1.2070	0.8538
10.00	1.7073	1.6432	1.4894	1.4286	1.1475

(iv) The linear form of yield function (eqn-e) infact follows 'the reciprocity law of diminshing return to scale' in which parametric ratio (i.e. B/A) indictes the rate of change in yield function.

In the above discussion, yield potential function, $P(\times)$ follows the form

$$P(\times) = [(AB\times^{-1})(1 + B\times^{-1})^{-1}] \ldots\ldots \quad (8)$$

where proportionate share of yield potential, $B\times^{-1}$, is a major determinant in the present case and the function shows that the magnitute of yield potential is controlled by it. It (proportional share of yield potential, Ps) deceases and, consequently, $P(\times)$ diminishes toward zero non-negatively as yield enhancing factors increase in yield potential function. Diminishing trend of yield potential alters the rate of yield curve.

YIELD-RATE CURVE

With diminishing return to intensity of yield function, the value of average product (Y/X) must always to greater than the marginal product (dY/dX). Average additive factor with the absorption rate of yield potential intensity [i.e., $Y/X = A(B+X)^{-1}$]. Further, the marginal product which is first order differential of yield function must determine the rate-factors. In th present case, yield rate curve follows the equation as :

$$dY/dX = -[B.A.(1+BX^{-1})^{-2}X^{-2}] = [\{(A-Y)/A\}.(Y/X)] \ldots \quad (9)$$

The inspection of above yield rate equation revaels that it is the product of and controlled by tow yield rate factors, namely (a) the potential resistance, Pr, and (b) the reproductive capacity of yield potential, Y/X. These rate - factors have a common parameter, that is yield potential intensity. It acts as the denominator in the equations as

$$\{(A-Y)/A\} = (BX^{-1}).(I + BX^{-1})^{-1} \ldots\ldots \quad (10)$$

and

$$(Y/X) = (AX^{-1}).(I + BX^{-1})^{-1} \ldots\ldots \quad (11)$$

Infact, the absorption rate of yield potential intensity subject to supply of yield factors,

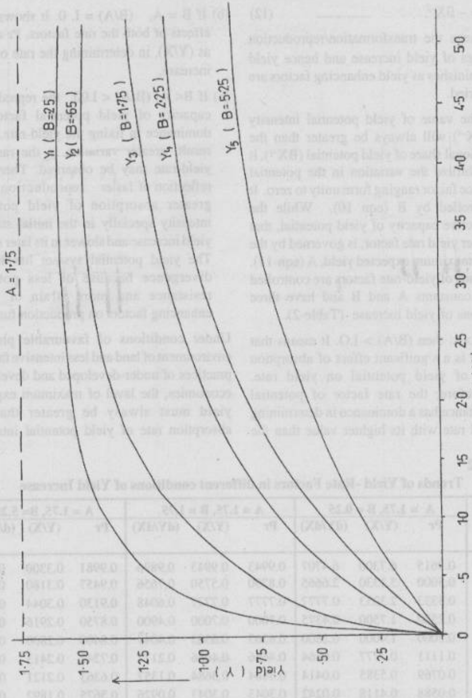

Fig. 1 : Yield Function at Various B

$Ip\ (x) = (I + BX^{-1})$, drops down with its decreasing rate because

$$dIp/dx = -BX^{-2}. \quad \ldots\ldots\ldots\ldots \quad (12)$$

It weakens the transformation/reproduction processes of yield increase and hence yield rate diminishes as yield enhancing factors are intensifried.

Since the value of yield potential intensity $(I + BX^{-1})$ will always be greater than the proportional share of yield potential (BX^{-1}), it will stablilize the variation in the potential resistance factor ranging form unity to zero. It is controlled by B (eqn 10). While the reproductive capacity of yield potential, that is another yield rate factor, is governed by the level of maximum expected yield, A (eqn-11). The trends of yield-rate factors are controlled by the constants A and B and have three conditions of yield increase (Table-2).

(a) If B>A, then (B/A) > I.O. It means that there is a significant effect of absorption rate of yield potential on yield rate. Therefore, the rate factor of potential resistance has a dominance in determining yield rate with its highter value than the value of reproductive capacity (see last part of Table-2).

(b) If B = A, (B/A) = I. 0. It shows equal effects of both the rate factors, Pr as well as (Y/X), in determining the rate of yield increase.

(c) If B< A, (B/A) < I.00. the reproductive capacity of yield potential factor has dominance in fixing the yield-rate. As a result, greater variation in the range of yield-rate may be observed. There is a reflection of faster reproduction with greater absorption of yield potential intensity specially in the initial stage of yield increase and slower in its later stages. The yield potential system has highter divergence because of less potential resistance and more strain of yield-enhancing factors on production function.

Under conditions of favourable physical environment of land and less intensive farming practices of under-developed and developing economies, the lavel of maximum expected yield must alwasy be greater than the absorption rate of yield potential intensity.

Table -2

Trends of Yield -Rate Factors in different conditions of Yield Increase

Input Level (X)	A = 1.75, B = 0.25			A = 1.75, B = 1.75			A = 1.75, B= 5.25		
	Pr	(Y/X)	(dY/dX)	Pr	(Y/X)	(dY/dX)	Pr	(Y/X)	(d/Y/dX)
0.01	0.9615	6.7300	6.4707	0.9943	0.9943	0.9896	0.9981	0.3300	0.3294
0.25	0.5000	5.3330	2.6665	0.8750	0.5750	0.7656	0.9457	0.3180	0.3007
0.50	0.3333	2.3333	0.7777	0.7777	0.7777	0.6048	0.9130	0.3044	0.2779
0.75	0.2500	1.7500	0.4375	0.7000	0.7000	0.4900	0.8750	0.2916	0.2551
1.00	0.2000	1.4000	0.2800	0.6363	0.6363	0.4049	0.8400	0.2800	0.2352
2.00	0.1111	0.7777	0.0864	0.4666	0.4666	0.2177	0.7242	0.2413	0.1748
3.00	0.0769	0.5385	0.0414	0.3684	0.3684	0.1357	0.6363	0.2121	0.1350
4.00	0.0588	0.4118	0.0242	0.3043	0.3043	0.0926	0.5675	0.1892	0.1074
5.00	0.0476	0.3333	0.0158	0.2592	0.2592	0.0672	0.5122	0.1707	0.0874
10.00	0.0244	0.1707	0.0042	0.1489	0.1489	0.0222	0.3443	0.1147	0.0395

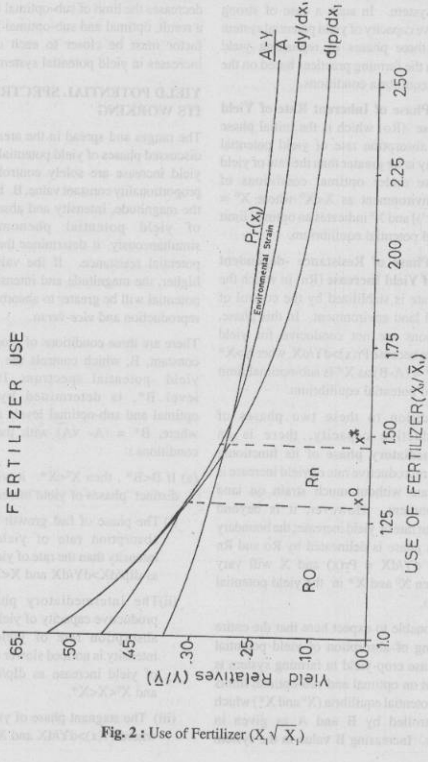

Fig. 2 : Use of Fertilizer $(X_1 \sqrt{X_1})$

Here the yield rate curve follows condition-o of yield increase (i.e., B<A) in the yield potential system. In such a case of strong reproductive capacity of yield potential system there are three phases of rate of yield increase in the farming practices based on the following conditions:

(1) The Phase of Inherent State of Yield Increase (Ro) which is the initial phase where absorption rate of yield potential intensity is greater than the rate of yield increase under optimal conditions of land environment as X<X° where X° = [B/(A^{..})] and X° indicates as optimal point of yield potential equilibrium.

(2) The Phase of Resistance -dependent Rate of Yield Increase (Rn) in which the yield rate is stabilized by the control of created land environment. In this phase, conditions are not conducive for yield increase because Pr(x)>dY/dX, where X>X* and X* = (A-B) as X* is sub-optimal point of yield potential equilibrium.

(3) In addition to these two phases of reproductive capacity, there is an intermediatory phase of its functioning where reproductive rate of yield increase is moderate without much strain on land environment. However, it is beyond inherent rate of yield increase; the boundary of this phase is delimited by Ro and Rn where dY/dX = Pr(X) and X will vary between X° and X* in the yield potential system.

It is reasonable to expect here that the entire functioning of mechanism of yield potential and increase crop-yield in farming system is dependent on optimal and sub-optimal limits of yield potential equilibria (X° and X*) which are controlled by B and A as given in equations. Increasing B value [illegible] increases optimal level of intensifying the effects of yield enhancing factors, while it decreases the limit of sub-optimal factors. As a result, optimal and sub-optimal levels of X factor must be closer to each other as B increases in yield potential system.

YIELD POTENTIAL SPECTRUM AND ITS WORKING

The ranges and spread in the areas of above discussed phases of yield potential system for yield increase are solely controlled by the proportionality constant value, B. It influences the magnitude, intensity and absorption rate of yield potential phenomena and, simultaneously, it determines the degree of potential resistance. If the value of B is higher, the magnitude and intensity of yield potential will be greater to absorb it for more reproduction and vice-versa.

There are three conditions of proportionality constant, B, which controls the working of yield potential spectrum. Its optimal level, B*, is determined by equating optimal and sub-optimal levels at X° = X* where, B* = (A- √A) with the following conditions:

(a) If B<B*, then X°<X*. There will be three distinct phases of yield increase as:

(i) The phase of fast growth with higher absorption rate of yield potential intensity than the rate of yield increase as dlp/dX>dY/dX and X<X°

(ii) The intermediatory phase of reproductive capacity of yield where the absorption rate of yield potential intensity is noticed slower than the rate of yield increase as dlp/dX <dY/dX and X°<X<X*.

(iii) The stagnant phase of yield increase as Pr(x)>dY/dX and X>X*.

Here the yield rate curve follows condition-c of yield increase (i.e., $B<A$) in the yield potential system. In such a case of strong reproductive capacity of yield potential system there are three phases of regualting yield increase in the farming practices based on the following equilibria conditions.

(1) **The Phase of Inherent Rate of Yield Increase** (Ro) which is the initial phase where absorption rate of yield potential intensity is far greater than the rate of yield increase under optimal conditions of land environment as $X<X^0$ where $X^0 = [B\sqrt{(A^{-1})}]$ and X^0 indicates an optimal limit of yield potential equilibrium.

(2) **The Phase of Resistance -dependent Rate of Yield Increase** (Rn) in which the yield rate is stablilized by the control of created land environment. In this phase, conditions are not conducive for yield increase because $Pr(x)>dY/dX$, wher $X>X^*$ and $X^* = (A-B)$ as X^* is sub-optimal limit of yield potential equilibrium.

(3)In addition to these two phases of reproductive capacity, there is an **intermediatory phase** of its functionig where reproductive rate of yield increase is moderate without much strain on land environment. However, it is beyond inherent rate of yield increase; the boundary of this phase is delineated by Ro and Rn where $dY/dX = Pr(x)$ and X will vary between X^0 and X^* in the yield potential system.

It is reasonable to expect here that the entire functioning of absorption of yield potential and increase crop-yield in farming system is dependent on optimal and sub-optimal limits of yield potential equilibria (X^0 and X^*) which are cointrolled by B and A as given in equalities. Increasing B value in the system increases optimal level of intensifying the effects of yield enhancing factors, while it decreases the limit of sub-optimal factors. As a result, optimal and sub-optimal levels of X factor must be closer to each other as B increases in yield potential system.

YIELD POTENTIAL SPECTRUM AND ITS WORKING

The ranges and spread in the areas of above discussed phases of yield potential system for yield increase are solely controlled by the proportionality constant value, B. It influences the magnitude, intensity and absorption rate of yield potential phenomena and, simultaneously, it determines the degree of potential resistance. If the value of B is higher, the magnitude and intensity of yield potential will be greater to absorb it for more reproduction and *vice-versa.*

There are three conditions of proportionality constant, B, which controls the working of yield -potential spectrum. Its optimal level B^*, is determined by equating optimal and sub-optimal levels as $X^0 = X^*$ where, $B^* = (A- \sqrt{A})$ with the following conditions :

(a) If $B<B^*$, then $X^0<X^*$. it will be three distinct phases of yield increase as:

   (i) The phase of fast growth with higher absorption rate of yield potential intensity than the rate of yield increase as $dIp/dX>dY/dX$ and $X<X^0$

   (ii)The intermediatory phase of reproductive capacity of yield where the absorption rate of yield potential intensity is noticed slower than the rate of yield increase as $dIp/dX <dY/dX$ and $X^0<X<X^*$.

   (iii) The stagnant phase of yield increase where $Pr(x)>dY/dX$ and $X>X^*$.

(b) If $B = B^*$, then $X^0 = X^*$. In this condition, spoecturm's equilibria are concentrated on one point as cited above. It distinguished the whole spectrum of higher strain of land environment as $Pr(x) > dY/dX$ in this phase.

(c) If $B > B^*$ in the working of yield potential spectrum, it means that the magnitude and intensity of yield potential is sufficient to use and its absorption rate may help to increase reproductive capacity beyond potential resistance. Therefore, situation on environmental strain can be seen before the point where absorption rate of yield potential equalized yield rare. As a result, $X^0 > X^*$ and all three phases of yield increase can be seen under this condition of yield potential spectrum.

EMPIRICAL SPECIFICATIONS

Majuli, a micro areal unit of about 925 sq.km and the biggest river-island of the world, is considered as s ageographical laboratory for testing the validity of the facts as described in the preceding section. It is bounded by the natural boundaries of the tributaries of Brahmaputra river and its main channel in the Upper part of the Assam plain of India (situated between 94° O' to 97° 35' E longitudes and 26°15' to 27°10' N latitused) with thick deposits of new alluvium soils of almost homogeneous ecological conditions surrounded by a number of beels, swamps and small streams. On account of flood plain topography, the texture of soil is sandy loam with gray mottles throughout (Aquic Udifluvent in soil taxonomy) as surveryd by the North-Eastern Centre of National Bureau of Soil Survey and Landuse Planning, Jorhat. The soil is ideal for the cultivation of paddy with high nitrogen contents (N/C 5.16%), medium availability of potassium (P_2O_5 form 50 to 80 kg/ha) and Phosphorus (K_2O 432.25 kg/ha) and is slightly acidic in reaction (pH=5.2) as analysed by Assam Agriculture University, Jorhat (c.f. Deka 1996). The soil moisture conditions are sufficient for paddy yield potential specially during monsoon season (June to October) with a suitable temperature ranging between 25° and 30°C when rainfall exceeds evapo-transpiration (Table-3).

In such an environment, irrigation is not an improtant yield-determining factor due to adequate availability of soil moisture. During the summers, the natural environment of paddy

Table-3

Available Moisture conditions for paddy Growth in Majuli

Months	J	F	M	A	M	J	J	A	S	O	N	D
T°C	16.30	18.14	21.58	23.81	26.22	28.37	28.57	28.73	27.73	25.57	21.33	17.20
P (in mm)	16.68	32.35	62.41	211.40	246.10	323.50	385.49	324.32	252.18	121.51	26.44	16.53
PE (mm)	83.56	89.78	126.38	144.77	174.45	187.22	193.14	184.42	162.23	142.59	107.87	87.90
P-PE (mm)	-63.88	-57.43	-63.97	66.63	71.65	136.28	192.35	139.90	89.95	-21.08	-81.43	-71.37

Abbreviation : T = Temperature, P= Precipitation, PE = Potential Evapotransportation.

NB : PE figures are calculated by using Conversion Tables prepared by Thornthwaite and Mather (1957)

Source : T and P data for 20 years averages (1975- 1995) have been collected from Regional Tea Research Centre, Tokolai (Joraht District)wyich is very close to the study area.

yield incrase is mainly influeced by two improtant yield-factores, namely, the use of chemical fertilizers (X_1) and the High Yielding Varieties (HYVs) of paddy seeds (X_2). However, degradation in land environment has been taking place with intensification of agricultural practices in the wake of extensive use of HYV technology in paddy cultivation (Bhavani 1995). The optimisation of created environment for paddy yield increase factors as cited above have been tested here and the impact of these factors on the absorption of yield potential intensity has been determined.

The statistics related to the paddy yield and its factores have been collected by conducting a survey under a programme for preparation of a report on the 'the Ecology of Rice Cultivation in Majuli' during March 1995. This year is recorded as favorable normal yield conditions for paddy growth. However, the use of chemical fertilizers and HYVs of paddy seed are recorded lower as 3.715 kg/ha and 51.408 kg/ha respectively than that of state as well as national levels. The mean value of paddy yield is calculated 23.463 qu/ha. However, the maximum expected paddy yieldlevel is estimated at 46.50/ha by considering the agro-ecological conditions of land environment of the upper Assam Plains Given by Indian Council of Agricultural Research, New Delhi (Prasad 1987, see Table 4.8 from Singh 1994).

In order to test the parametric estimations of the model, carried out with the help of yield statistics of 118 paddy farmers of various size of landholdings, the raw data of paddy yield and its factors have been transformed into its relative weightages dividing the data series of variables by their means. The 'mean-unity' data for paddy yield (Y) and its two main yield-enhancing factors, viz. use of chemical fertilizers (X_1) and HYVs (X_2), have been used to determine the parametric values of yield function by means of non-linear regression as two -factors yield function of the following form as:

$$Y(x_{1,2}) = [A(1+B_1X_1^{-1} + P_2\, X_2^{-1})] \;...... \qquad (13)$$

The parametric values of the function are given in Table 4.

Table-4

Estimated Values for Parameters, B, for Equation. (7) based on Statistics collected form Majuli farmers.

$Y(x_{1,2})$	Constant A	B	MSE	R^2
$Y(x_{1,2})$	1.9818	0.52716	1.673	0.9832
$Y(x_{1,2})$	1.9818	0.79272	1.749	0.9615

Abbreviations: (1) MSE = Mean Standard Error which is at its.05 significant levels (d.o.f. = 116).(2) R^2 = Coefficient of Determinant.

The results given in Table-4 that the Mean Standard Errors are small and the coefficients of determinant correspondingly larger. It can, therefore, be said that there is a significant difference at its 5.0 percent deviation between the observed and the theoretical distributions. The optimal conditions and phasing characteristics of yield potential spectrum in Majuli area of Brahmaputra valley are also given accordingly, which are as for:

$Y(x_1)$, $X_1^{\circ} = \{B_1/(\sqrt{A-1})\} = 1.2924$ (that refers to 4.8012kg/ha),

$X_1^{*} = (A\text{-}B_1) = 1.45464$ (that is 5.4040kg/ha,

$B_1^{*} = (A-\sqrt{A}) = 0.57403$ (i.e., 2.1325 kg/ha).

and

$Y(x_2)$, $X_2^{0} = \{B_2/(\sqrt{A\text{-}1}\} = 1.9447$ (99.9731 kg/ha),

$X_2^{*} = (A\text{-}B_2) + 1.18908$ (i.e., 61.1282 kg/ha),

$B_2^{*} = (A-\sqrt{A}) + 0.57403$ (i.e.,29.5100 kg/ha)

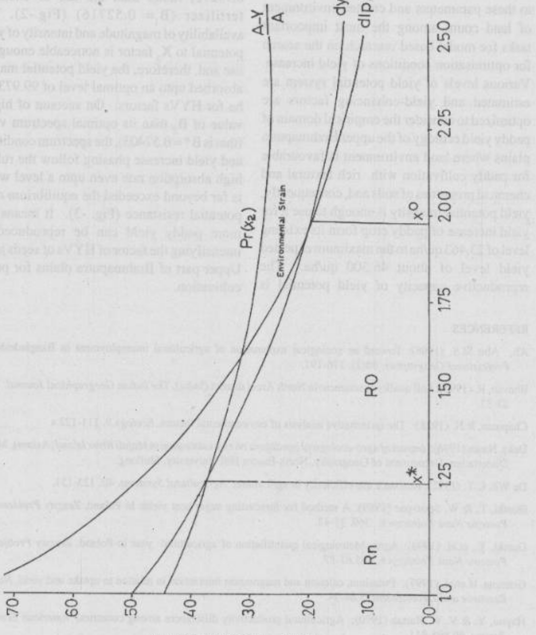

Fig. 3 : High Yielding Varieties Seeds -- Use of HYV Seeds $(X_2\sqrt{X_2})$

DISCUSSION AND SUMMARY

The description of yield potential parameters and the modelling of yield function with respect to these parameters and created environment of land count among the most impoortant tasks for model based research on the search for optimisation conditions of yield increase. Various levels of yield potential system are estimated and yield-enhancing factors are optimized to consider the empirical domain of paddy yield ecology of the upper Brahmaputra plains where land environment is favourable for paddy cultivation with rich textural and chemical properties of soils and, consequently, yield potential intensity is enough to use it for yield increase of paddy crop form its existing level of 23.463 qu/ha to the maximum expected yield level of about 46.500 qu/ha. The reproductive capacity of yield potential is significantly high subject to those low rate enhancement factors. Reproductive capacity is recorded very high for HYVs seeds (B_2 = 0.79272) rather than the use of chemical fertilizer (B_1= 0.52716) (Fig.-2). The availability of magnitude and intensity of yield potential to X_2 factor is noticeable enough to use and, therefore, the yield potential may be absorbed upto an optimal level of 99.973 kg/ha for HYVs factors. On account of higher value of B_2 than its optimal spectrum value (that is $B^* = 0.57403$), the spectrum conditions and yield increase phasing follow the rule of high absorption rate even upto a level which is far beyond exceeded the equilibrium of its potential resistance (Fig. -3). It means that more paddy yield can be reproduced by intensifying the factor of HYVs of seeds in the Upper part of Brahmaputra plains for paddy cultivation.

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