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Original Article

Production Agronomy- Contemporary Concepts for Sustainable Agriculture

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Abstract

Agronomy means field management and production agronomy refers to systems of field management meant to achieve high sustainable productivity. It involves planning and execution of intensive cultivation systems aimed to maximize productivity, vital to feed and clothe increasing population. Agronomist does it by pooling latest research information on all aspects of cultivation and plant growth on a continual basis and putting them in a system that is efficient and economically viable. Some of the contemporary reflections on this discipline is spelt out.

Keywords

Agronomy; Productivity; Systemsmanagement.

Introduction

Introduction: Agronomy (Ancient Greek ãñüò *agrós* 'field' + íüìïò *nómos* 'law') is a science and a practice that looks at agriculture from an integrated, holistic perspective of all basic and applied sciences like, mathematics, biology, physics, chemistry economics, ecology, statistics, plant genetics, plant physiology, meteorology, and soil science for producing plants for food, fiber, fuel and land reclamation. Current trends implicate Agronomy in many issues related tothe environmental impact of agriculture, and extracting energy from plants. Soil based agriculture systems are multiple component ones involving interactions of soil, water, air (atmosphere), plant and climate which determine productivity. Main components of the system embrace several sub-components which in turn includes micro-components (Annexure 2). Such a complex system is difficult to analyze in totality by phase rule application and as such information was sought thru experiments with one or more varaibles at a time in different agro- climatic zones defined by soil types and landscapes where many of the production componentsoccur at more or less at constant levels. Modern approach to productivity starts with defining Agro climatic potential of a region in terms of temperature, rainfall and sun shine hours and plans ways and means to exploit it to maximize production.

Water and nutrients are calculated for the targeted yield and given based on whole plant analysis and water requirement for bio-mass production.

Plant is considered as a factory which convert the inputs (nutrients water and air) in a medium of flowing water into bio mass using solar energy (for carbohydrates) and respiration or chemical energy (for manufacturing other compounds in various bio-cycles).

Factors which are Related to Productivity:

A: Direct Factors

1. Supply of raw materials-nutrients,carbon-dioxide, oxygen, water
2. Sources of energy- Sunlight (PAR for photosynthesis and the rest of spectrum for warming the environment and sustaining tissue temperature).

*B: Indirect Factors (*referring to those undertaken to reduce avoidable losses)

a. Plant protection measures to prevent or to reduce

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damages to health of plants

b. Weed management to reduce competition mainly to that of nutrients and water in the environment in which plants are grown for specific purposes

Raw materials for growth of plants are made available thru terrestrial bio-cycles. Some important pathways of replenishment of resources are given below;

1. *Carbon-Dioxide:* CO_2 concentration in the atmosphere is maintained by Carbon cycle– decomposition of organic matter, respiration of living organisms (animals and Plants), burning of fossil fuels etc.,
2. *Water:* Theterrestrial equilibrium is maintained by natural cycle of evaporation and precipitation, underground water storage and its exploitation for irrigation. Soil structure helps in water retention in soil pores against evaporation and gravity and sustained release to plants for a longer period after the cessation of rain and irrigation
3. *Nutrients*: Nutrient balance is maintained byweathering of soils and the decomposition of organic matter against losses thru leaching. During thunder and lightning, atmospheric Nitrogen is converted into oxide forms which, in soil, are transformed into ammonium and nitrate forms by bio activity. In the soil, losses of nitrogen also occur thru de- nitrification and leaching pathways.
4. Sources of energy-i)solar energy (PAR for photosynthesis) (ii) chemical energy or the respiration energy using part of carbohydrate synthesized for biomass synthesis (conversion of carbohydrates to biomass) and for life activities such as transport mechanisms for movement of water and nutrients and for maintaining water and temperature balance within the tissues.

Water balance in the tissues is vital for optimal functioning of life activities. Biomass, within the cell, is dispersed in water medium in colloidal state and the stability of colloidal medium depends on moisture content and osmotic regulations. Tissue moisture is maintained by transpiration currents whose main duty is to maintain tissue temperature against its increase during biomass synthesis. The plants also have developed various resistance barriersfor water movement within the plant to conserve water during dry periods besides a reduction in bio-mass synthesis. The metabolic processes are irreversibly damaged if the moisture content drops below 88% of the optimum value. For e.g., If 70% moisture is required for keeping the biomass dispersed within the cell, the irreversible damage to the medium will occur if the moisture content drops below 61.6%.(i.e. 88 % of 70). Water isstored in soil micro pores by surface tension forcesand is made available for a longer time and sustains the growth of plants even after cessation of rains and irrigation. Thus soil moisture plays an important role in maintaining water balance during dry months and short periods in between irrigations. Organic matter bestows porous structure to soil by binding clay particles with humic acids and thus plays an important role in preserving soil fertility for free movement of air, water and nutrients in the rhizhosphere. A model production program adopted

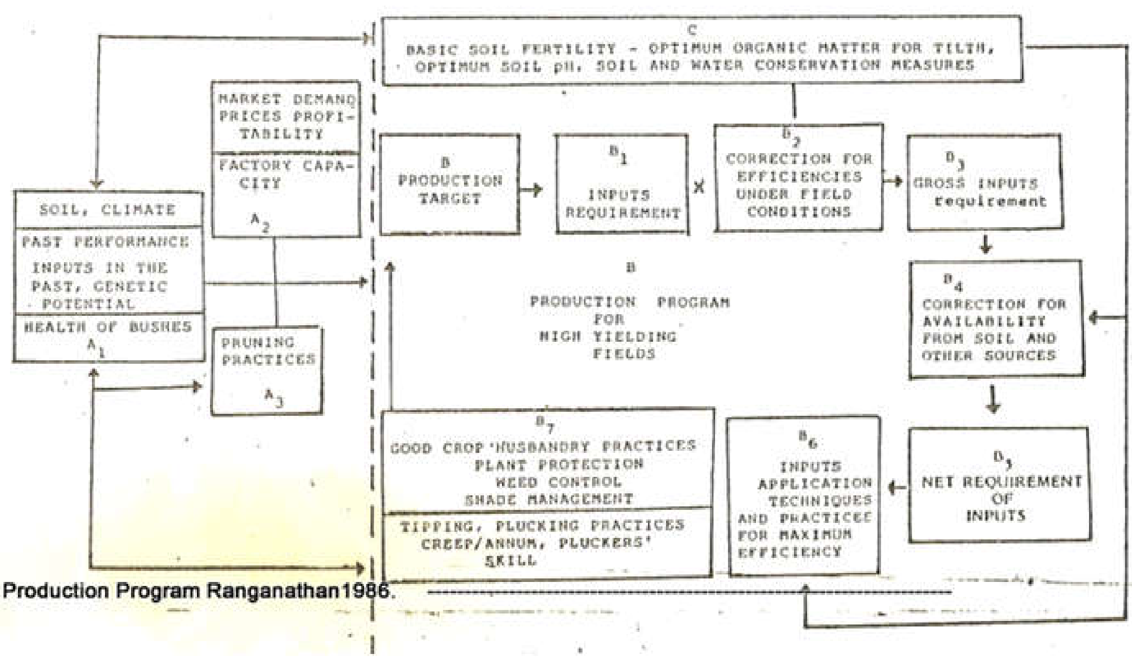

Fig1 Production Program Ranganathan1986.

in Tea in nineteen eighties is shown in Figure 1.

Neoteric productivity models define the role of each component and quantify their share to ultimate productivity.

1. Soil: Medium for air water and nutrient movement
2. Atmosphere: Source and sink for oxygen and carbon-dioxide
3. Plant: Uses the inputs fed thru soil and air, manufactures biomass of which part is taken as the economic end product
4. Water: Nutrient carrier, medium for dispersal of biomass in living tissues: temperature regulator and maintaining *source-sink* gradient for continuance of metabolic processes.

Current Trends in Productivity Management

Maximum productivity of a crop depends on ideal combination of climatic components and unlimited availability of water, CO_2, O_2 and nutrients.

Maximum theoretical yield or NPP *(NET PRIMARY PRODUCTION under unrestricted supply of water and other resources)* is worked out from the solar energy incident on earth surface (@ 400 calories $cm^2 d^{-1}$ in tropics and sub- tropics), photo synthetic efficiency (PE), respiration losses, energy required for bio synthesis (@ $19 MJkg^{-1}$ biomass) and the efficiency of natural recycling process limited to 60 to 70 % by thermodynamic laws. Roughly NPP is about 480 t biomass per ha per year i.e. 14 to 16% of biomass equivalent of energy incident on surface. Recent relook on these aspectsthru satellite studies show that solar radiations incident on earth can fix 200 t C $ha^{-1}yr^{-1}$ roughly equal to 450 t biomass $ha^{-1}yr^{-1}$ (delucia et.al 2014). Harvest index, then, determines the productivity in terms of economic end product.

Ideal climatic condition rarely exists and iscaused by variations inclimate, soil heterogeneity and topography. Several attempts were made in the past to correlate climate, soil and crop factors with productivity. Of all the attempts to quantify climate in terms of various factors which influence it, one that developed by late Dr. Devanathan of TRI, SriLanka has a physiological basis. He showed that the first organic compound made from inorganic materials (CO_2, and H_2O) is the simple sugars which are then converted to other biomass by the plant andtherefore the productivity isrelated, ultimately, to the efficiency of the photosynthetic apparatus. The photosynthetic yield (y)) is a function of temperature (t) to the extent it influences the rate of photosynthesis (after Baldry, et al 1966, as quoted in Devanathan, 1976 at unlimited supply of carbon-di-oxide and water), sunshine hours(S), and rainfall (R). Biomass is then synthesized using respiration energy by burning a portion ofcarbohydrates synthesized. This is normally referred as respiration losses and it varies from crop to crop. It is lower in crops grown for carbohydrates than for fats and proteins for obvious reasons.

$Y=\int tRS+1$ (0r) $y= KtRS+1$ -----Devanathan1976

"K" is a constant prompted by respiration losses, harvest index and management constraints "t" temperature coefficient (to the extent it influences the rateofphotosynthesis (after Baldry,et,al1966,as quoted in Devanathan(1976)article); "R" rainfall in cm; "S" Sunshinehours,+1 added as correction for diffused light and unrecorded sunshine at boundaries at critical light saturation

Devanathan used rainfall fall as such for correlation studies. High correlation with productivity was obtained in regions with rainfall received in all most all the months. Butit failed in regions with intermittent drought months with zero rainfall as "y" becomes zero in these months.

As the plants utilize the water stored in the soil for short periods between two spells of rainfall and twosuccessive irrigations thru transpiration currents, soil water play a vital role. There is a loss of soil water by evaporation also. Both of them together are called"Evapotranspiration". Ranganathan (1987) defined "R" as the efficiency with which the water balance is maintained against gains and losses. It, therefore, depends on soil properties for water storage and retention, depth of root penetration, rainfall and evapotranspiration. It is referred as water (rainfall &Irrigation) use efficiency coefficient. He also added temperature coefficient which determine the rate of biomass synthesis reflected in the growth of plants. In plants there is a time lag between the time of photosynthetic output and its conversion to biomass manifested in growth of plants which vary from crop to crop. A correction has to be provided for this time lag (Annexure 2).

Productivity Targeting

It starts from valuing NPP of the region from solar data under unlimited availability of water and nutrients. Physiologists have shown that about 250 kg water has to pass thru the plant for synthesis of one kg of biomass.The water available from rainfall and irrigation (expressedin rainfallunits) is calculated by multiplying their sum by water use efficiency. From the available water and water requirement for bio synthesis, the maximum possible productivity with unlimited supply of nutrients iscomputed

Productivity is the biomass synthesized from the nutrients. As such nutrient requirements are to be applied for the biomass to be synthesized for the productivity targeted. Nutrient requirements are estimated from whole plant analysis. Requirements over and above what soil could contribute in a given time are met from extraneous sources as fertilizers or manures; Nutrient management is, thus, the most vital one in any production management system.

Soil structure is very important for the movement of air, water, and nutrients besides retention and releasing them to the roots Soil depth of 100 cm with not less than 0.8% Om , around 60% porosity, will have a bulk density slightly above 1.0 and will store about water equivalent to 36 cm rainfall. Porosity higher than 80% results in bulk density lower than 1.0, making soil particles float and lost in the runoff water during rains. Minimum salt concentration in the soil i) is required to sustain the physicochemical properties of soil to safe guard the soil tiith on the long run and ii) minimum Calcium concentration in soil solution in the rhizhosphere is to be maintained for enhancing cell permeability for uptake of nutrients by roots and to reduce efflux of "K" ions from roots (Viet effect). Viet effect is not generally a problem in soils with pH above 4.5. Other polyvalent ions substitute the role of Calcium in soils with pH below 4.5

The plant factor: Thoseto be looked into from productivity point of view are; (a) Planting density depending on spreading ability of the cultivar decides how soon leaf area index (Photosynthetic surface) can be built above 2.5. (b) Information on type of photosynthetic mechanism, Respiration losses, salt sensitiveness related to vacuolar loading and unloading, the mechanism of conserving CO_2 concentration in leaf tissues and its release to photosynthesis help in understanding the adjustments necessary to get maximum benefit out of the system designed on modern concepts on productivity management.Information collected for system management to maximize productivity with respect to *Tea* plant is shown in Annexure 3 as an example.

Summing Up

Various steps taken by Agronomist to set a target for productivity and achieving it are:

1. The theoretical maximum productivity is grasped from NPP under *unconstrained availability of resources* from the solar energy incident on earth surface.
2. Reckoning water limiting threshold productivity of a region from physiological data on water requirement of plants - (a) with only the rainfall and its distribution and (b) with added irrigation potential accessible.
3. Computation of soil nutrients limiting thresh hold limit when other factors are not limiting
4. Fixing the target between those of soil nutrients limiting thresh hold limit and the water (Rainfall + Irrigation) limiting threshold productivity and achieving it by applying nutrients based on whole plant analysis for the set target.

The system does not exempt attention to be given to the importance of soil structure maintenance, crop specific husbandry practices, plant protection measures and soil and water conservation measures.

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References

1. Daniel H White and Mark Howden S. Climate and its effects on crop productivity and management in Soils, *Plant Growth and crop production* 2010; 1:1-35. UNESCO-EOLSS.
2. Daniele Vieira Guimara˜es, Maria Isidoria Silva Gonzaga, Ta´cio Oliveira da Silva, Thiago Lima da Silva, Nildo da Silva Dias, and Maria Iraildes Silva Matias. Soil organic matter pools and carbon fractions in soil under different land uses, *Soil & Tillage Research* 2013; 126:177–182:
3. Devanathan MA.W. The quantification of climatic constraints on plant growth. Tea Quarterly 1976; 45:43-72.
4. Frank B. Salisbury. Approaching the photosynthetic

limits of crop productivity, *EIR* 1988; 15(40):20-22.

5. Kandiah S. & Devadasan T. Quantification of weather parameters to predict tea yields. Tea Quarterly 1980; 49:25-33.
6. Ranganathan, V. and S. Natesan. Agrometeorology of productivity of tea in south India. Proceeding of the National Seminar on Agrometeorology of Plantation Crops, March 12-13, Pilicode, Kerala, 2987.p.73-78. Ed. G.H.L.H.V. Prasada Rao and R.R. Nair, Publ. Kerala Agricultural University, Trichur-680 651, India, 1987.
7. Ranganathan V. and C.K. UnnikrishnanNairC.K. 1988:, Production agronomy – pragmatic approach to higher productivity *Proc. Joint Area Scientific Symposium (JASS-4)*, December 1-3, 1988.p.11. Munnar.
8. V.Ranganathan and S.Natesan, Agronomic pathways of yield response in tea to correction of zinc deficiency and control of pests Proc. PLACTOSYM VI 1984.
9. Ranganathan V. Nutrient Management in Tea, *The Planters' Chronicle* 1986; 81(5):174-81.
10. Ranganathan V. Production agronomy with special reference to mineral nutrition of tea in South India. *Proc. 30th Tocklai Conference*, 1988.p.56-62. Published by TRA, Jorhat, Assam, India
11. Ranganathan, V. Manuring Tea, IFA World fertilizer use manual: International Fertilizer Paris. 1992.
12. Ranganathan V. Climate versus Productivity, *Indian Journal of Plant and soil;* 2014 January-June; 1(1):11-14.
13. Ranganathan V, 2014: Harvest index in Productivity Management, *Indian Journal of Plant and soil;* 2014 July –December; 1(2):55-60.
14. Ranganathan V. Root Distribution and Quantification of Available water holding Capacity of Soils, *Indian Journal of Plant and soil;* 2015 January-June; 2(1).
15. Ranganathan V. ApproachingTheoritical Limits of Productivity in Coconut, *Indian Journal of Plant and Soil;* 2015 January-June; 2(1).
16. Ranganathan V. Shoot Generations in Productivity Management in Tea (camellia L. spp.), *Indian Journal Of Plant and Soil;* 2015 July-December; 2(2):87-91.
17. Ranganathan V. TargetingProductivity in Rice (Oryza sativa L.), *Indian Journal of Plant and Soil;* 2015 July-December; 2(2):125-131.
18. Ranganathan V. Harvesting the critical determinant in achieving the Target productivity In Tea (Camellia Spp.) *Indian Journal of Plant and Soil;* 2016 January -June; 3(1):35-40.
19. Ranganathan V. Chasing the Theoretical Limits of Productivity Sugarcane (Saccharum Spp.) *Indian Journal of Plant and Soil;* 2016 January- June; 3(1):41-45.

Annexure 1: Ranganathan (1987, 2014) Agro-climatic index

Y= ∫K (tRS *RT) : tRS*RT is called " Ø" (Agro -climatic potential -ACP) - Ranganathan 1987, 2014
("tRS" determines the photosynthetic yield and "RT" determines the rate of biomass synthesis reflected in the growth of plants)

Y=b+ KØ: with time lag correction **$Y = b + K_1 Ø_1 + K_2 Ø_2$** where $Ø_1$ is the ACP of the current period and $Ø_2$ is th ACP of previous period (days equivalent to time lag prior to current period).

"K" is a constant prompted by respiration losses, harvest index and management constraints "t" temperature coefficient (to the extent it influences the rate of photosynthesis (after Baldry, et al 1966, as quoted in Devanathan (1976) article);

"R" represents the probability of the length of duration the water supply system maintains the leaf water potential at critical level (88% of the optimum level) during illumination;

$R = 1 - e^{-(Fm + Rm - Et)/F}$ where Fm- field capacity in the beginning of a period, Rm rainfall during the period, Evapotranspiration during the period, all in rainfall units; "F" the maximum water holding capacity of the soil; "Fm+Rm" is limited to "F" as excess water percolate down due to gravity

"S" Sunshine hours, +1 added as correction for diffused light and unrecorded sunshine at boundaries at critical light saturation:

"T" = $1-e^{(tc-tm)/to-tc)}$; tc- critical temperature for growth: tm– mean daily temperature for period; to = temperature at which net photosynthetic yield is zero or respiration losses exceeds the photosynthetic yield. **"tc–tm "** isnumerically equal to day degree ; **"to-tc"** " is the maximum day degree above which the net photosynthesis is zero.

Annexure -2 ; components of productivity determinants

No.	Main	Components: Sub	Components: Micro
1	Plant	Variety	Susceptibility to pests and diseases (plant protection measures
		Age	Tolerance to stress conditions
		Physiological	Efficiency of photosynthetic apparatus
		Biological	Growth and spreading Habit
2	Soil	Physical	Texture, Structure, water holding capacity
		Chemical	Om content , Nutrients supplying power
		Physicochemical	PH ,Redox potential, ion exchange potentials
		biological	Bio-activity of soil flora and fauna
3	Climate	Temperature	Max.,Min., and diurnal variations
		rainfall	Total rainfall and its distribution
		Light	Length of sunshine hours per day in various growth phases
4	Atmosphere	CO_2	Wind for circulation
		O_2	Wind, Bioactivity
		Humidity	Evapotranspiration and water balance
5	water	Quantity	Rainfall and irrigation potential
		Quality	Salinity and alkalinity
		Retention	Soil properties for sustained release for growth

Annexure 3: CROP DATA --TEA

1. *Well drained Acidic soils with pH below 5.0 ;texture –Loams; depth of soil min 100cm. Porosity around 60 % , bulk density just above 1.0; and aminimum OC content iof 0.8%.*
2. *Crop depression occurs when Ca content in mature foliage exceeds 0.8% and heavy metal toxicity (particularly Mn) occurs when it falls below O,6%*
3. *Minimum Caconc.required in outer soil solution to reduce efflux of ionsand carbohydrates from roots is 1x10^{-4}M/litre . Optimum concentration in mature leaves varies between o.6 and o.8 % corresponding to soil pH 4.8 ±0.2*
4. *Energy requirement for biomass synthesis is 4500 calories per gram on DM basis*
5. *Net Net energy conversion - 0.37-0.42 % on total radiations or 0.80 to 0.91 % of PAR*
6. *Of the incident light 10to 30 is reflected: 70% absorbed, out of which 5% is used for Photosynthesis and the rest converted to heat*
7. *Without shade leaf temp. may go up to 10 t0 15^{0}C above ambient temp. and with shade it is only 1to2^{0}c : Tea responds well under shade- 60 to 70% of sunlight in the open*
8. *Shade reduces 70% of the radiation damage to a distance of twice its height.*
9. *Photosynthesis increases with temp. up to 35^{0}C and then declines sharply*
10. *Respiration increases faster than photosynthesis and continues up to 48^{0}C. Hence the net photosynthesis decreases with temp. and it is negative at temp. above 40^{0}C.*
11. *Respiration losses in tea is around 30%. Harvest index is low in tea- 7 to 14 % on total biomass production and 18 to 30 % on that of above ground parts*
12. *Photo periodism- Min. day length of 11 hours and 15 seconds is required for growth: Below this level tea goes to dormancy.*
13. *Night temp. below 14^{0}C retards growth and ceases below 12.5^{0}C*
14. *Growth rhythm ; in normal conditions tea turns banjhi after 7or 8th leaf take a dormant period and again grow repeating the rhythm and grow into a tree. In bush culture, any stress be it nutrient, water , or climate turn a bud to banjhi.*
15. *Tea uses sugars manufactured for osmotic regulation of tissue moisture by retaining them for 24 hr. It creates a time lag of 4 to 5 weeks between time of manufacture and expression in terms growth. As such the yield of the current month is the reflection of photosynthetic yield of the previous month.*
16. *Unlike other dicots, tea has adopted during its evolution in acidic soils in humid regions C-4 photosynthetic path way normally seen in monocots. This requires potassium aided by silicon to play an important role in absorption, retention and release of CO_2 for photosynthesis' in highly degraded soils low in soluble silica. Application of soluble silicates helps to improve the response to N.Tea roots have alower CEC compared to other dicots for competing for monovalent ions with other charged surfaces in the soil environment.*
17. *There is no phloem transport of foliar applied nutrients and hence the nutrients absorbed thru roots are transported by xylem to various tissues but redistribution thru phloemfrom foliage tissues is not efficient . More over there is no vacuolar loading and unloading of ions absorbed by roots or thru foliage before they are utilized by plants for their growth. Hence they accumulate in cells in absence of growing conditions as in water stress conditions leading to salinity damages*