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Effect of Plant Population and Planting Geometry on Growth and Yield Parameter of Crop

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SUMMARY

Plant spacing in the field is very important and plays a significant role in determining plant growth and development. Plant spacing should be as existing in two directions: within row spacing and between row spacing. At a given plant population, as row spacing decreases the plant spacing within the row increases and results in a more equidistant plant spacing. At a fixed row width, as plant population increases the plant spacing within the row decreases and interplant competition increases. Obviously, both factors can be adjusted to provide optimal plant spacing and typically plant population increases as row spacing decreases. The expectation would be that narrow row spacing and increased plant population would improve light interception and that would then have a cascade effect, increasing crop growth rate and potentially improving seed production. An important consideration would be that as plant population increases the available source (light) per plant decreases.

INTRODUCTION

A low plant population can be competitive with higher plant populations as long as the plant population is uniformly distributed in the field. At lower populations interplant competition is reduced and each individual plant has a greater opportunity to produce more seeds. Research has shown that photosynthetic rate is greater and maintained longer in response to larger sink size (seed number) by increased protein levels in leaves and reduced leaf senescence of older leaves. The risks associated with reduced plant populations is that pods form closer to the ground increasing harvest losses and the plant must maintain a high growth rate and leaf area throughout the season to remain competitive with higher populations. Soybean is able to compensate for poor stands by producing more branches resulting in yields comparable to higher plant populations. However, low plant populations may result in lower pod height, lodging of lateral branches, and higher weed populations, all of which may result in harvest losses.

How Do Plant Populations Affect Yield?

The optimum density or plant population for any given situation results in mature plants that are sufficiently crowded to efficiently use resources such as water, nutrients, and sunlight, yet not so crowded that some plants die or are unproductive. At this population, production from the entire field is optimized, although any individual plant might produce less than would have occurred with unlimited space. Many factors influence the optimum plant population for a crop: availability of water, nutrients and sunlight; length of growing season; potential plant size; and the plant’s capacity to change its form in response to varying environmental conditions (morphological plasticity). One example of this is tillering, which allows small grain crops like winter wheat to produce the same number of heads and final grain yield in a given area over a wide range of plant densities. Modern corn cultivars, on the other hand, have been selected to produce few if any tillers. Consequently, corn has a relatively narrow range for optimum plant population.

For corn, optimum plant population can be influenced by hybrid maturity. Research in the Corn Belt by Pioneer Hi-Bred International found that harvest populations for early maturing hybrids (less than 100 days to crop relative maturity, or CRM) are optimized at populations above 30,000 plants per acre. For hybrids with maturities between 100 and 113 CRM, the optimum plant population was 28,000 plants per acre. For late maturing varieties (more than 113 CRM) the optimum plant population was 26,000 plants per acre. They found the risk of not achieving full grain yield potential was greatest when final stands were below 26,000 plants per acre. Remember that to achieve a given harvest population, seeding rates need to be greater than the harvest population to account for seed germination rates of less than 100 percent and less-than-ideal seed bed conditions.

Using 48 years of historical climate data, computer crop simulations suggested that, although corn yields could be increased with increased plant population density in years with above-normal precipitation, there were not enough wet years to justify plant populations above 12,000 plants per acre. In dry beans, optimum established plant populations depend on market class, plant type and productivity, and individual producer experience with particular fields and varieties. Indeterminate semi-vine (Type III) pinto and Great Northern varieties usually perform best at 60,000 to 80,000 established plants per acre. Higher plant populations (75,000 to 90,000 plants per acre) are preferred for determinate bush (Type I) and indeterminate upright (Type II) varieties because they have a more compact growth habit; that is, they have less morphological plasticity. Light red kidney and black bean varieties that possess Type I and Type II growth habits are often planted to achieve an established plant population of 85,000 to 100,000 plants per acre. Generally, higher plant populations are suggested for lighter, less productive soils than for heavier, more productive soils. Yield potential will generally decrease with established plant populations below 40,000 to 50,000 plants per acre under full irrigation.

Dryland bean producers typically target plant populations between 20,000 and40, 000 plants per acre. Optimum plant populations for maximum sugar yields in irrigated sugarbeets fall between 30,000 and 40,000 plants per acre. Achieving a high plant population becomes more difficult as row widths increase, because in-row spacing between sugarbeet plants becomes quite small in wider rows. Sunflowers can compensate somewhat for differences in plant population through adjustments in head size. Higher populations are generally planted for oil type than for confection type hybrids. Plant populations for oilseed hybrids range from 14,000 to 22,000 plants per acre. The lower populations are used under dryland conditions when soil-water levels at planting are low and the higher populations are used under irrigation. The plant population range for confection-type sunflower hybrids ranges from 12,000 to 18,000 plants per acre.

Growers who want to reduce seed cost by planting at lower plant populations should be careful not to get too low for their particular crop or conditions. Crops or crop varieties with the capacity to change form in response to varying environmental conditions, for example winter wheat or dry beans with a Type III growth habit, are likely to be least affected by a reduction in plant population. (Drew Lyon-2009)

Row Spacing, Plant Population, and Yield Relationships

The manipulation of row spacing dimensions, plant populations, and the overall spacial arrangement of crop plants in a field has been the subject of considerable discussion among farmers and agronomists for many years. The crop canopy has often been manipulated by row spacing and population adjustments in an attempt to improve yields, production efficiencies, and profits. Similarly, plant breeders have altered plant architecture in an effort to improve light interception by crop plants. The development of conventional, narrow, and ultra narrow (UNR) crop systems and breeding for plants with columnar or bush-type architecture are examples of these types of manipulations to improve yield. The process of crop production requires the conversion of energy in sunlight into dry matter by fixation of CO2 from the atmosphere through the process of photosynthesis. Leaves are the primary site of photosynthesis in crop plants. Therefore, one might assume that the greater the number of leaves in a field, the better interception of sunlight and higher the yield.

A common way of describing the surface area of leaves in a field is by the leaf area index (LAI). The LAI is the ratio of the leaf surface area (upper side only) of the crop to the ground area. The LAI for a crop will normally increase as the crop canopy develops. LAI values of greater than or equal to 4 (i.e. 4 times more area of leaves than ground) have been measured for irrigated cotton in Arizona. Cotton plants will also be effected to some extent by the fact that the leaves track the movement of the sun (heliotropic movement), which increases interception of light by the canopy. However, with an increasing LAI there will also be an increasing amount of shading of lower leaves in the canopy. As a result, agronomists recognize that an optimization of LAI is important in realizing the most efficient interception of sunlight and optimum photosynthesis.

Another primary objective in a crop production system is to direct a high proportion of the dry matter into harvestable parts of the crop plant. The relationship between the harvestable portions of the plant (e.g. lint or seedcotton yield in cotton) and the total amount of dry matter produced by the crop is often referred to as the harvest index (HI). An important goal in a crop production system is to generate a high HI. For cotton production systems this translates to producing as many bolls per unit area (e.g. per acre) as possible to realize high yields. Therefore, maximum cotton production is a direct function of efficiently utilizing resources such as sunlight, water, and nutrients. The balance between vegetative and reproductive growth (i.e. harvest index for cotton) is critical in relation to any effort to improve yields.

As noted above, an essential aspect of any crop production system is the development of a crop canopy that optimizes the interception of light, photosynthesis, and the allocation of dry matter to harvestable plant parts (yield). A crop canopy is commonly managed by manipulating row spacing, plant population, and plant type.

Yield per unit area generally increases with plant density. Although, as plant density is increased yield per unit area will approach an upper limit, plateau, and then decline. Yield per plant tends to decrease with increasing plant density because competition for resources (light, water, and nutrients) between adjacent plants intensifies. .

What is competition?

Competition is the struggle between individuals with in population foravailable resources, when the level of resources is below the combined need of the members of the population.

How does competition occur in plants?

Crop plants are not grown in isolation but in closely spaced populations. In the early phase of growth, individual plants are small and widely spaced and do not interfere with each other. At some point, as the plants grow, they start to interfere with their neighbours and competition begins. Two plants, no matter how close, do not compete with each other so long as the growth resources are in excess of the needs of both. When the immediate supply of a single necessary factor falls below the combined demand of the two plants, competition begins.

Types of Competition

1. **Competition for nutrients**: Nutrient uptake increases with increase in plant population. Higher population under low fertility conditions leads to development of nutrient deficiency symptoms because of competition.
2. **Competition for light**: Competition for light may occur whenever one plant casts a shadow on another or within a plant when one leaf shades another leaf. In early plant growth stages, there will be little mutual shading and even at relatively low light intensities the plant will be able to photosynthesize with full efficiency. As the plants grow, mutual shading increases and light becomes a limiting factor.
3. **Competition for water**: The success of any plant in community for water depends on the rate and competitiveness with which it can make use of the soil water supply.
4. **Intra-specific and inter-specific competition**: In populations of similar genotypes, in the absence of weeds, the competition is intra-specific (with in species), where different species of crops are grown, in mixtures and where weeds present, the competition is inter-specific (between species).

Plant population and growth

• High plant density brings out certain modifications in the growth of plants.
• Plant height increases with increase in plant population due to competition for light.
• Sometimes it may happen that moderate increase in plant population may not increase but decrease plant height due to competition for water and nutrients but not for light.
• Leaf orientation is also altered due to population pressure. The leaves are erect narrow and are arranged at longer vertical intervals under high plant densities.

Plant population and yield

• Decrease in yield of individual plant at high plant density is due to the reduction in the number of ears or panicles.
• Ex: - Red gram produces about 20 pods per plant at 3.33 lakh plants/ha
(30x10cm) while it produces more than 100 pods per plant at 50,000 plants/ha (80x25cm).
• Under very high population levels plant become barren, hence optimum plant population is necessary to obtain maximum yield.

Optimum plant population

Optimum plant population for any crop varies considerably due to environment under which it is grown. It is not possible to recommend a generalized plant population since the crop is grown in different seasons with different management practices. E.g.:- Red gram plants sown as winter crop will have half the size of those grown in monsoon season. Optimum plant population is 55,000 plants/ha for monsoon season crop of red gram and this is increased to 3.33 lakh plants/ha for winter crop; as low temperature retards the rate of growth, higher population is established for quicker ground cover. In sorghum, when the climate is favourable during pre-anthesis period, the optimum population is two lakh plants/ha and when it is not congenial for growth during pre-anthesis, it is four lakh plants/ha.

Planting Pattern

Planting pattern influences crop yield through its influence on light interception, rooting pattern and moisture extraction pattern. Different planting patterns are followed to suit different weed control practices and cropping systems. Plant geometry refers to the shape of plant while crop geometry refers to the shape of space available for individual plants. Crop geometry is altered by changing inter and intra-row spacing.

Square planting

It is reasonable to expect that square arrangement of plants will be more efficient in the utilization of light, water and nutrients available to the individuals than in a rectangular arrangement. In wheat, decreasing inter-row spacing below the standard 15-12 cm i.e., reducing rectangularity, generally increases yield slightly. In crops like Tobacco, intercultivation in both directions is possible in square planting and helps in effective control of weeds. However, square planting is not advantageous in all crops. Groundnut sown with a spacing of 30x10cm (3.33 lakh/ha) gave higher pod yield than with same amount of population in square planting. Pod yield is reduced either by increasing rectangularity or approaching towards square planting.

Rectangular planting

Rectangular planting sowing the crop with seed drill is the standard practice. Wider inter-row spacing and closer intra-row spacing is very common for most of the crops, thus attaining rectangularity. This rectangular arrangement is adopted mainly to facilitate intercultivation. Sometimes only inter-row spacing is maintained and intra-row spacing is not followed strictly and seeds are sown closely as solid rows.

Miscellaneous planting arrangements

Crops are sown with seed drills in two directions to accommodate more number of plants and mainly to reduce weed population. Crops like rice, finger millet are transplanted at the rate of 2-3 seedlings per hill. Transplanting is done either in rows or randomly. Every alternate row is skipped, and the population is adjusted by decreasing intra-row spacing, it is known as paired row planting. It is generally practised to introduce an intercrop. (Reddy & raddy)

Plant Geometry

Crop geometry is one of the important factors, which has to be maintained optimum level to harvest maximum **solar radiation** and utilizes the soil resources effectively. Modifying plant density, spacing, and geometry are important agronomic practices that influence utilization of soil water and rainfall, and the overall control of soil evaporation under dryland conditions. Decreasing row width and increasing plant population depleted soil water during the early growing season in grain maize at the University of Ibadan, Nigeria (Babalola & Oputa 1981). Narrow row spacing in sorghum increases shade, reduces energy and evapotranspiration, and increases the competition between plants for water and light in the crop canopy (Baumhardt 2004). Growing maize in clump geometry may help the plants conserve moisture, remain green longer, and yield more grain and biomass than row spacing plants under extremely dry environmental conditions. Growing dryland crops in clumps may reduce environmental stress, increase grain yield, HI, and seed mass, and decrease leaf temperature

Effect of Planting Geometry

Devlopment effect

Perhaps the most abundant literature on planting geometry effect on growth and performance is for soybean .The effect of soybean intra-row plant spacing seems less important than the effect of inter-row spacing. This may result largely from the soybean's great capacity to morphologically compensate for changes in competition (Hinson and Hanson, 1962). It is observed that maximum yields determinate soybean at 0.9-m inter row spacing with 4-cm intra- row spacing of seed .As a result, significant skips in the row have nearly no effect on soybean. Increasing soybean plant densities usually result in increased plant height, height of lowest pod, and lodging potential.

Radiation interception

A major motivation for changing plant geometry is to improve light interception .wide-row soybean culture result in a slower increase in leaf area index (LAI) than for narrow-row culture. As result of earlier canopy closer, a densely shaded canopy floor provides better weed control under narrow rows. The quantity and pathway of radiation intercepted by plant canopy are both affected by canopy geometry, this produces numerous environmental alternations including temperature distribution within soil and canopy, foliar distribution of photosynthetically active radiation (PAR), and changes in canopy light quality

Water use

Doss and Thurlow (1974) compared soybean performance in wide and narrow rows with high and low population under irrigated and non irrigated condition. They found no influence on yield of inters-or intra-row spacing under irrigated conditions but found higher yields under low populations in non irrigated treatment. In earlier studies found that the highest water-use efficiency (yield/evaporation) in their narrow row treatment .doubling plant population by decreasing inter-row spacing by one half had a doubling effect on transpiration from flowering to maturity.

Nutrient use

Nitrogen uptake rate and soil N depletion can be expected to occur more rapidly under narrow-row culture of soybean because more nearly equidistant spacing results in increased density of root. It is observed higher N2-fixation rates for higher plant population and narrower row spacing.

CONCLUSION

Plant population and planting geometry can have a significant effect on crop growth and yield. The final plant population determines the crop's yield. The optimum plant population for each crop needs to be identified to get the maximum yield per unit area. High plant density can cause leaves to become narrow and erect, and to be arranged at longer vertical intervals. Crop geometry can be optimized to improve resource utilization and productivity. Plant height increases with plant population due to competition for light. When plants are widely spaced, dry matter yields increase linearly with plant density. Under low plant population, individual plant yield is higher due to wide spacing. Under rain fed conditions, high plant population can deplete soil moisture before maturity

REFERENCES

Babalola, O., and C. Oputa. "Effects of planting patterns and population on water relations of aize." *Experimental Agriculture* 17.1 (1981): 97-104.

Baumhardt, R. L., P. W. Unger, and T. H. Dao. "*Seedbed surface geometry effects on soil crusting and seedling emergence."* Agronomy Journal 96.4 (2004): 1112-1117.

Doss, Basil Dewel, and D. L. Thurlow. "Irrigation, row width, and plant population in relation to growth characteristics of two soybean varieties 1." *Agronomy Journal* 66.5 (1974): 620-623.

Hinson, Kuell, and W. D. Hanson. *"Competition studies in soybeans."* (1962): 117-23.

Kalany Publication , New Delhi , India Pp193-202

Lyon, Drew J., "How Do Plant Populations Affect Yield?" (2009). *Press Releases from Panhandle Research and Extension Center*. Paper 19

M. Asghar Malik, S.H. Shah, 2001 *"Effect of Various Planting Geometries on the Growth, Seed Yield and Oil Content of New Sunflower Hybrid*" (SF-187) International Journal Of Agriculture & Biology1560–8530/2001/03–1–55–56

Pava. A.S, Nagalikar. V. P. *2011 "Influence of planting geometry on the growth characters, seed yield and economics of transplanted Pigeonpea" Karnataka J. Agric. Sci.,24 (3) : (390 - 392)*

Reddy, T.Y and Reddi, G H Sankara 2009.*Principles of agronomy*. Book.