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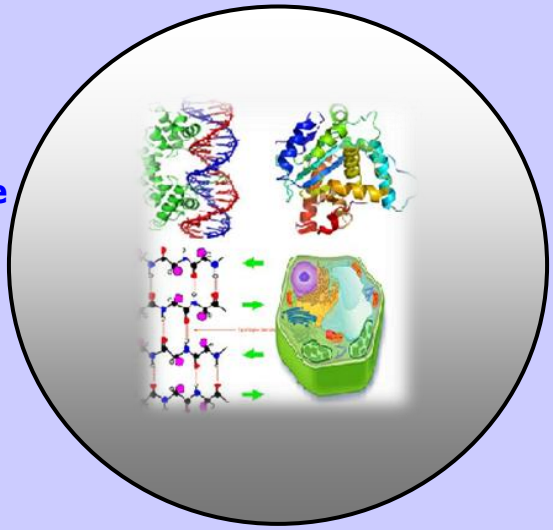

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RESEARCH PAPER

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A Study of Soil Structural Variations in Relation to Microsporogenesis in Barley

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ABSTRACT

The plant environment includes a number of factors that finally shape up the whole metabolism of the plants. These factors include Soil, Water, Air and interactions etc. The changes in any of these factors lead to changes in the physiological processes and in turn changes in the biochemical environment within the cell. This is the plants' response to cope up with the change or to adapt itself in the new set of environmental factors. These changes have definite and measurable effects on cytology and cell divisions. Physiological correlations of these natural changes have been done extensively but cytological studies on this aspect are very few. In view of this, the present study was undertaken with soil structure and texture being the variable under scan for cytological changes.
Keywords: Barley, Chromosomal Aberrations, Microsporogenesis and Soil Variables.

INTRODUCTION

The study of plant environment, which includes, in broad sense, both soil and climatic factors cover a vast field of research. The factors, which might have major influence on growth of plant, are moisture, temperature, photoperiod, soil structure etc. The study of the microclimate and the performance of the plants only provide a picture of the resulting effects brought about by a given changing set of conditions. But the role of individual factors and their delicate interplay in growth regulation cannot be assessed from such studies. However, soil structure is one of the few factors of plant environment that lend themselves to a considerable degree of control without any elaborate mechanized installation. It is amongst many factors that run counter to the natural establishment, growth and development of the plants.

The role of soil in the soil-plant-atmosphere continuum is unique. It has been demonstrated that soil is not essential for plant growth and indeed plants can be grown hydroponically (in a liquid culture). However, usually plants are grown in the soil and soil properties directly

affect the availability of water and nutrients to plants. Soil water affects plant growth directly through its controlling effect on plant water status and soil structure does it indirectly through its effect on aeration, temperature, and nutrient transport, uptake and transformation. The understanding of these properties is also helpful in good irrigation design and management.

The soil system is composed of three major components: solid particles (minerals and organic matter), water with various dissolved chemicals, and air. The percentage of these components varies greatly with soil texture and structure. An active root system requires a delicate balance between the three soil components; but the balance between the liquid and gas phases is most critical, since it regulates root activity and plant growth process.

Soil texture refers to the distribution of the soil particle sizes. The mineral particles of soil have a wide range of sizes classified as sand, silt, usar and clay. The proportion of each of these particles in the soil determines its texture. All mineral soils are classified depending on their texture. In addition almost all soils contain some organic material, particularly in the top layer. This organic material, together with the fine soil particles, contributes to aggregate formation, which results in the improvement of the soil structure. Soil structure refers to the arrangement of soil particles into certain patterns. The structural pattern, the extent of aggregation, and the amount and nature of the pore space describe the structure of the particular soil.

The size, shape, and arrangement of the soil particles and the associated voids (pores) determine the ability of a soil to retain water. It is important to realize that large pores in the soil can conduct more water more rapidly than fine pores. In addition, removing water from large pores is easier and requires less energy than removing water from smaller pores. Sandy soils consist mainly of large mineral particles with very small percentages of clay, silt, and organic matter. In sandy soils there are many more large pores than in clayey garden soils. In addition the total volume of pores in sandy soils is significantly smaller than in clayey garden soils (30 to 40% for sandy soils as compared to 40 to 60% for garden soils). As a result, much less water can be stored in sandy soil than in the garden soil.

To study soil-water-plant relationships it is convenient to subdivide soil water into water available to the plant and water unavailable to the plant. After the soil has been saturated with water one can observe a vertical, downward movement of water due to gravity. In sandy soils, this drainage process happens quickly. Usually 24 hours is sufficient to remove almost all of the gravitational water in sandy soils. The exact time depends on the soil type; the drainage of the gravitational water generally takes a little longer for clayey garden soils and much longer in fine usar soil. With heavy compost soils, too much water retention may be a problem. In most soils, however the gravitational water moves out of the root zone too rapidly to be used by the plants. The remaining water is stored under tension in the various size pores. The smaller the pore the greater the tension and the more energy required to remove its water. As a result plants have the ability to remove water only from the certain size pores. The removal of water from very small pores requires too much energy and consequently, this water is not available to the plant. In addition clogging of pores with water also reduces the availability of air to the roots. There is also some water, which is very closely bound to soil particles. This water is called hygroscopic water. It is also very difficult to remove, and is not available to the plants.

Although, physiological and biochemical studies related to soil structural variations have been done in the past but cytogenetical correlation of the findings is lacking altogether as far as the available literature is concerned. The present study thus tries to bridge this gap in knowledge.

MATERIAL AND METHODS

For assessment of the effect of soil structure variation, four sets of soil variables were used for both the plants:-

1. Garden soil set- It had normal garden clay without any manure.
2. Sandy soil set- It had a mixture of pure sand and garden clay in ratio 2:1.
3. Usar soil set- It had a mixture of usar soil and garden clay in a ratio 2:1.
4. Pure compost set- It had pure dried cow dung compost mixed with negligible amount of clay for binding.

Each set was planted in 10 replicates using designated soil type along with suitable controls for comparison. At the time of flowering, buds were fixed in Carnoy's Fluid 3:1 Absolute Alcohol: Glacial Acetic Acid for cytological analyses. Slides were prepared using Acetocarmine squash technique.

RESULTS

Table 1 gives a comparative account of cytological behavior in plants of barley growing under control and variable soil conditions. The controls exhibited almost perfect meiosis (0.47% abnormal PMCs) with regular formation of 7bivalents at Metaphase I and normal 7:7 separation at Anaphase I. It was interesting to note that the chromosomal abnormalities induced by changes in soil variations.

Highest total abnormality (12.26%) was observed in case of plants growing on usar soil. This was closely followed by those on pure compost (11.07%). Abnormality percentage was low in case of garden clay (7.4%) and sand (5.40%). The abnormalities were represented by both physiological as well as spindle ones. Clastogenic anomalies like fragmentation and micronuclei were also observed.

Stickiness was among the most common anomalies at Metaphase. It was highest (1.6%) in usar soil set, 1.4% in pure compost set, 1.33% in garden soil set and 0.8% in sandy soil set. Clumping of chromosomes was high in PMCs of garden soil set (1.07%), moderate in usar soil set (0.8%) and pure compost set (0.87%) but low in sandy soil set (0.2%).

Spindle anomalies were equally represented in form of late movement of bivalents to the metaphase plate, disturbed orientation and precocious movement of chromosomes. Late movement of chromosomes was highest in case of pure compost set (1.06%) while lowest in case of sandy soil set (0.47%). Precocious movement of chromosomes was not observed at all in case of garden soil set and sandy soil set. It was 0.27 % in the plants of usar and 0.46% in those of pure compost sets. Disturbed orientation of chromosomes was a common anomaly being high in garden soil set (0.67%), usar soil set (0.80%) and pure compost set (0.87%). It was, however low in sandy soil set being only 0.33%.

Multivalent associations of chromosomes were observed in all sets except the garden soil set while univalent were comparatively uncommon and so was fragmentation of chromosomes.

Stickiness and multipolarity were the most common Anaphase anomalies. Stickiness was recorded in 1.2% PMCs in garden soil set, 0.6% PMCs in sandy soil set, 1.27% PMCs in usar soil set and 1.07% PMCs in pure compost set. Multipolarity was high in usar soil set (0.73%) and pure compost set (0.8%) and low in garden soil and sandy soil set (both 0.47%). Bridges were comparatively fewer but observed in all sets except garden soil set. Laggards were also not seen in garden soil set. Unequal separation at Anaphase was recorded only in usar soil set (0.2%). Highest frequency of non-synchronous disjunction was observed in usar soil (0.6%).

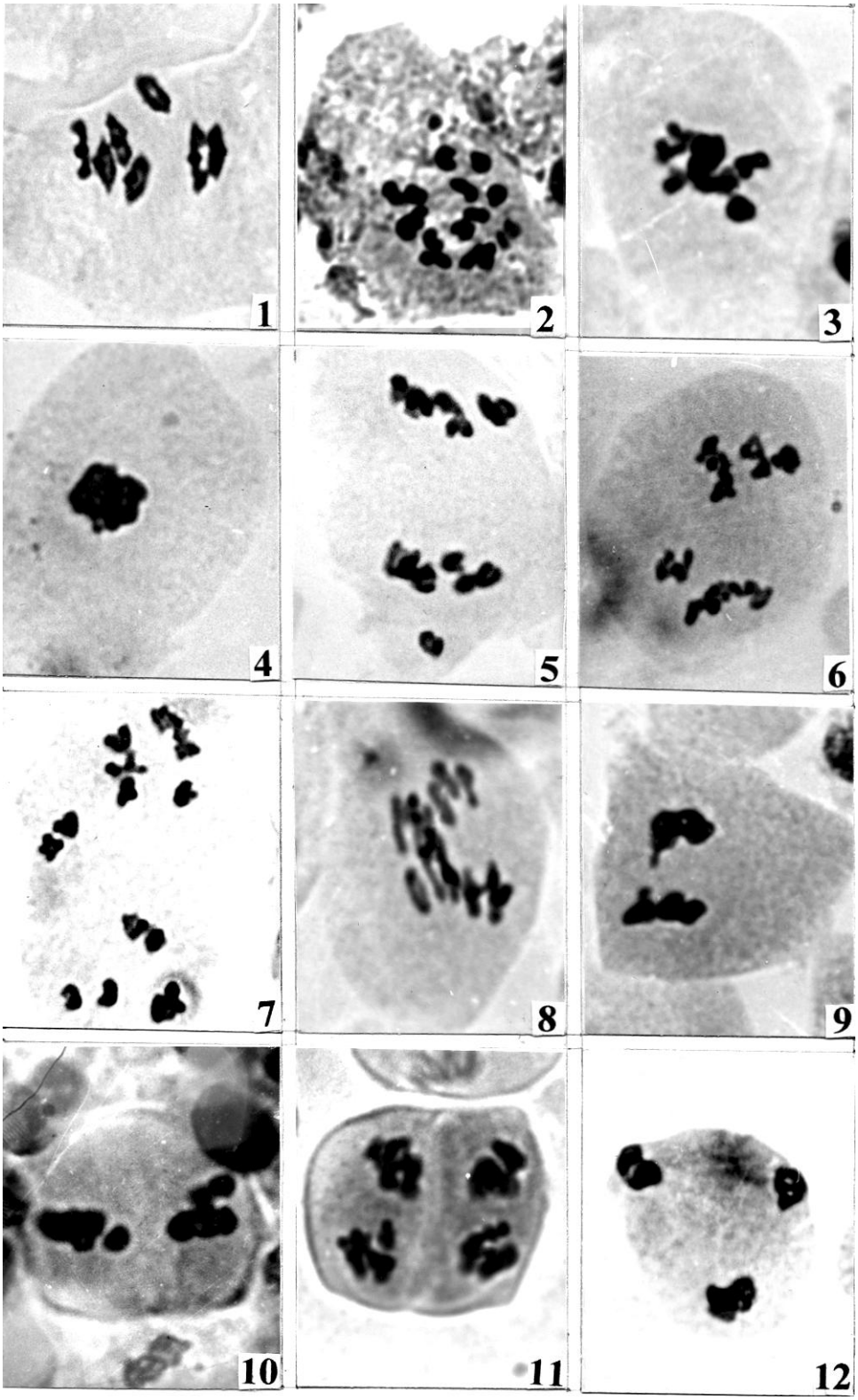
Micronuclei were common to all treatment sets being 0.6% in pure compost, 0.53% in usar soil, 0.4% in garden soil and 0.27% in sandy soil. Laggards at Telophase were absent in garden soil set while bridges at garden and sandy soil set. Polyads were present in low frequency in garden soil, sandy soil and usar soil sets while triads were seen in usar soil and pure compost sets.

Shrinkage of PMCs was common in all the sets. It was highest in pure compost set (0.8%) while lowest in sandy soil set (0.2%).

Table 1. Comparative cytological abnormalities induced by variation in soil structure in barley.

Treatment	CF/biv ± SE	Metaphase I/II abnormalities (%)									Anaphase I/II abnormalities (%)						Telophase I/II Abn (%)			Cytoki-nesis Abn (%)		Other Abn (%)		T Ab (%)
		Lm	Do	Pc	Mv	Uv	Fg	St	Cl	Sa	Lg	Br	Us	Ns	St	Mp	Lg	Br	Mn	Tr	Pa	Cy	Sh	
Control	1.79±0.01							0.20	0.07						0.13								0.07	0.47
Garden	1.49±0.05	0.87	0.67					1.33	1.07	0.80					1.20	0.47			0.40		0.07		0.53	7.40
Sand	1.77±0.05	0.47	0.33		0.27			0.80	0.20	0.40	0.40	0.27		0.20	0.60	0.47	0.40		0.27		0.13		0.20	5.40
Usar	1.22±0.05	1.00	0.80	0.27	0.53	0.33		1.60	0.80	0.93	0.53	0.40		0.60	1.27	0.73	0.46	0.20	0.53	0.33	0.20		0.73	12.26
Compost	1.32±0.01	1.06	0.87	0.46	0.27		0.40	1.40	0.87	1.00	0.46	0.27	0.20	0.27	1.07	0.80	0.53	0.33	0.60	0.13			0.80	11.07

Lm=Late movement of bivalents; Do=Disturbed orientation of chromosomes; Pc=Precocious movement of chromosomes; Mv=Multivalent formation; Uv= Univalent formation; Fg=Fragmentation of chromosomes; St=Stickiness of chromosomes; Cl=Clumping of chromosomes; Sa=Secondary association of bivalents; Lg=Lagging chromosomes; Br=Bridge formation between poles; Us=Unequal separation of chromosomes at anaphase; Ns=Non synchronous disjunction; Mp=Multipolarity; Mn=Micronuclei; Tr=Triads; Pa=Polyads; Cy=Cytomixis; Sh=Shrinking of PMCs



Figures 1-12. Cytological Aberrations in barley microsporogenesis under variable soil conditions, 1. Disturbed orientation at Metaphase I, 2. Scattering and univalent, 3. Stickiness, 4. Clumping, 5 -7. Spindle abnormalities, 8. Late separation, 9. Clumping at Anaphase I, 10. Clumping at Metaphase II, 11. Laggards at Anaphase II, 12. Tripolarity.

DISCUSSION

Induction of physiological changes in response to conditions of variation in structure and moisture level of soil is quite obvious since the plant tries to survive in adverse conditions by adapting itself. These changes are brought about not only on macro level also on the micro level i.e. cellular level. For survival, the plant may even undergo genetic modification thus leading to change in the protein quality and quantity. It may also lead to increase or decrease in various cellular products including sugars and carbohydrates.

If we observe the parameters in case of variation in soil composition, we can see that the barley plants performed well in sandy as well as in un-manured garden clay. The probable reason for this seems to be the need of aeration to the roots and rapid passage of water from soil. The tillers however were fewer in case of sandy soil set and plants had slender erect morphology, perhaps to conserve and minimize the use of water. The seeds were shorter but heavier. The chromosomal anomalies were also fewer, which show the adaptation of barley plants to well drained and porous soils. Clay is the main source of many plant nutrients and has a certain level of exchange capacity. The sand is however inherently deficient because of its higher porosity and loosening of nutrients by leaching in humid climates. Our results did not support the study as plants growing on sand performed better than those on clay.

In case of usar and pure compost sets the parameters were poor and chromosomal anomalies high. The main reason seems to be the poor drainage offered by these soils. Besides this, usar soil offered too low and pure compost too high nutrient content. Higher organic content of soil confirms the higher return of exchangeable cations by phytocycling of nutrients but higher presence does not confirm active uptake by plants. In fact, creation of anoxic conditions at root surface leads to lower uptake and poor growth. In case of pure compost set the plants had relatively good vegetative growth but very poor fertility while in usar soil set none was satisfactory.

Most of the cytological abnormalities are indicative of stress effects on chromosomes. Most common abnormality was stickiness, which is physiological anomaly. Jayabalan and Rao (1987) opine that it occurs due to change in cytochemical by balanced reactions. It may also be due to the dissociation of nucleoproteins and alteration in the pattern of organization (Evans 1962), which might have occurred due to reduced cell moisture. Secondary associations observed among bivalents might be interpreted as a result of manifold chromosome arrangement due to defective duplication, interchanges or stickiness (Stebbins 1950). Multivalents are usually formed due to translocations but they may also result due to stickiness.

Changes in plant environment might have brought about disturbances in cell functioning, leading to distorted formation of spindle fibers may be the cause of spindle abnormalities like unorientation, a precocious movement early separation and laggards. Unorientation of chromosomes may lead to unequal segregation of chromosomes at Anaphase 1 (Khan 1996). Laggards may also bring about unequal separation.

Defective division at first stages of division leads to defects in second phases of division and various abnormalities accumulate to make the gametes sterile. Reduction in yield causes a reduction in seed set and thus, the yield.

CONCLUSION

The study provides a basis for reduction in growth and chromosomal abnormalities caused due to environmental stresses that are faced by the plant when it is planted in soil structural conditions that are not very favourable for its growth. The plant tries to survive and as a reaction produces chemicals which in turn bring about changes in the physiological and cytological levels. This is a field which is relatively untouched while deciding the course of mutagenesis in mutation breeding studies. However soil structure as well as other environmental variants can be exploited for their role in bringing about changes in physiology and carrying forward the effects to genetic levels. It can also help in better planning of irrigation and use of soil types.

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