EFFECT OF DUST POLLUTANTS ON GROWTH, DEVELOPMENT AND YIELD OF WHEAT (*Triticum aestivum* L.)

THESIS

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DECLARATION OF STUDENT

I hereby declare that the experimental work and its interpretation of the thesis entitled "EFFECT OF DUST POLLUTANTS ON GROWTH, DEVELOPMENT AND YIELD OF WHEAT (*Triticum aestivum* L.)" or part thereof has not been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis/publication of any University or Scientific Organisation. The sources of materials used and all assistance received during the course of investigation have been duly acknowledged.

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CERTIFICATE

This is to certify that the thesis entitled "EFFECT OF DUST POLLUTANTS ON GROWTH, DEVELOPMENT AND YIELD OF WHEAT (*Triticum aestivum* L.)" submitted in partial fulfilment of the requirement for the degree of Doctor of Philosophy in Agriculture of the Punjabrao Krishi Vidyapeeth Akola is a record of bonafide research work carried out by Shri Deorao Vithuji Durge under my guidance and supervision. The subject of the thesis has been approved by the student's advisory committee.

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ABBREVIATIONS USED

cm	-	centimeter(s)
mg	-	milligram (s)
g	-	gram(s)
kg	-	kilogram(s)
/	-	per
%	-	percentage
°C	-	degree celsius
D.F.	-	degree of freedom
M.S.	-	mean squares
C.D.	-	critical difference
S.E.	-	standard error
i.e.	-	that is
viz.	-	namely
et al.	-	et alia (and associates)
Fig.	-	figure(s)

CHAPTER I

INTRODUCTION

India is a developing country. After independence, much attention was paid on the establishment of small to big industries with the object of achieving self sufficiency and increasing employment potential. During this phase, much stress was given on the economic benefits of industrilization while least attention was paid on their harmful effects. The rapid industrilization has now posed many problems of environmental pollution.

The famous episodes of air pollution 1) Mense valley of Belgium in 1930; 2) Donora, Pennsylvania, U.S.A. in 1948; 3) London, U.K. in 1952 and Bhopal Gas episode, India in 1984 have provided significant evidences of their worst effects. These episodes have posed many questions and opened a new area of research.

During recent years, increased demand of cement for industrial and urban developments has caused rapid expansion of cement factories in India. These industries are posing problems of particulate emissions around the factories. Cement kiln dust is a mixture of calcium, potassium, aluminium, sodium and silica oxides. During last 20 years, number of cement factories have been installed in Vidarbha region. These factories are emmitting large amount of dust in atmosphere. The dust settles on crops and soil in the area around the factories and forms hard crust when it comes in contact with moisture. Crops and vegetations in the vicinity of factories have been reported to be damaged by dust pollution. Harmful effects of particulate pollutants on plant growth have been reported by Singh and Rao (1980 a, b); Lal and Ambasht (1980, 1982) and Oblisami et al.(1978).

Considering the adverse effects of dust pollution, present investigation on "Effect of dust pollutants on growth, development and yield of wheat" was undertaken to fulfill following objectives :

1) To study the comparative effect of soil and cement dust pollution on growth, development and yield of wheat.
2) To find out detrimental concentration.
3) To assess the yield losses, if any.

* * *

kind of environmental pollution that has been reported in most industrial towns and metropolitans of India and abroad.

Major sources of air pollution are particulate and gaseous matter which get released by the burning of fossil fuels such as coal, petroleum etc. Out of these comes a variety of emissions (1) fine particles (less than 100 μ in dia) (2) Coarser particles (over 200 μm), large carbon particles and heavy dust that is quickly removed by gravity from the air.

The toxic effects of particulate matter on animals and human can be classified as 1) intrinsic toxicity due to chemical or physical properties, 2) interference with clearance mechanism in the respiratory tract, or 3) toxicity due to adsorbed toxic substances Eugene Vanergrift et al (1971) reported particulate air pollution status in USA Annexture-1.

2.2 Growth and Development

Peirce (1909) reported that small cement dust particles clog the stomata of oak (Quercus lobata), fruit trees and grape wines. The coarser particles formed more or less extensive crusts, thus covering over the stomata. The accumulation of dust on the surface of leaves constituted mainly a mechanical interference with the proper exchange of those gases concerned in respiration and photosynthesis which might be more or less injurious.

– Annexture-1. ~~Table – A~~

Table-A Particulate Air pollution status in U.S.A.

	Source	Emission in Tons per year
1.	Fuel combustion Electric utilities Industrial use	5,95,300
2.	Crushed stone, sand and Gravel	4,60,000
3.	Agricultural and Related operations	17,68,000
4.	Iron and steel	15,64,000
5.	Cement	9,34,000
6.	Lime	5,73,000
7.	Clay	4,68,000
8.	Fertilizer and phosphate Rock	3,27,000
9.	Petroleum refining	45,000
10.	Asphalt	2,18,000
11.	Ferroalloys	1,60,000
12.	Coal cleaning	94,000
13.	Carbon black	93,000
14.	Acids	16,000
15.	Non ferrous metals	6,02,000
16.	Total	1,80,81,000
17.	Normal standards for maximum 2-hours Emission	Particulate matter
	a. Steam power plants	0.1 lb/million BTU Fired
	b. Portland cement plants kiln	0.3 lb/ton feed
	c. Clinker cooler	0.1 lb/ton feed
	d. Municipal incinerators	0.08 grain/scf at 12% CO_2
	e. Sulphuric acid plants	0.15 lb/ton acid(H_2SO_4)

Eugene Venergrift et al. (1971).

Darley (1966) demonstrated that the finer particles of certain cement kiln dusts collected from electrostatic precipitators did interfere with CO_2 exchange and in some cases caused considerable leaf injury in pinto bean. Injury resulted from the combination of a relatively thick crust deposit and the toxicity of alkaline solutions formed when dusts were deposited in the presence of free moisture. The results further suggested that calcium content alone might not be the only indicator of whether a dust might be injurious, and much more needs to be known about the effects of the interaction of chemical composition, particle size and deposition rate.

Singh and Rao (1968) conducted the experiments to assess the effects of cement dust on plants, using wheat as test plants under pot culture with open top polythene chamber. Cement dust was dusted uniformly on plants daily in the morning when they were 40 days old at the rate of 7 g/m^2/day. Dusting was continued till the plants attained the age of 100 days. Results showed that the dusted plants exhibited stunted growth, accompanied with reductions in length of their root, shoot, total and effective tiller number, leaves and grain per spike. Mineral contents of dusted plants also differed from control.

Manning (1971) investigated effects of continuous emissions of limestone dust from quarries and processing plants on leaf condition, foliar disease incidence and leaf surface microflora of native wild grapes, sassafras and hemlock. Grape and Sassafras leaves with moderate dusts deposits had more fungal leaf spots than comparable leaves without visible dust deposits.

Dusty grape and sassafras leaves were darker green in colour than leaves without dust deposits, but all were comparable in size. The terminal new growth of hemlocks with heavy dust deposits was greatly reduced in length when compared to terminal growth on hemlock trees without visible dust deposits.

Brandt and Rhoades (1972) determined the effects of dust accumulation on structure and composition of a forest community. The sites were similar in all respect except for dust accumulation. One site, the control, had essentially no dust accumulation, whereas the other had heavy accumulation from limestone processing plants. When compared with the control site, significant changes in structure and composition were observed in the seedling, shrub and tree strata of the experimental site. Leading dominants in the control site were Quercus prinus, Q.rubra, and Acer rubrum, whereas those in the dusty site were Quercus alba, Q.rubra and Liviodendron tulipifera.

Brandt and Rhoades (1973) recorded annual ring measurements on four tree species to determine the effects of lime stone dust on lateral growth. The reduction in lateral growth of at least 18% was shown for *Acer rubrum*, *Q. prinus* and *Q. ribra*. Lateral growth of *Liriodendron tulipifera* was however, increased by 76%.

Rangasamy *et al.* (1973) observed increase in composition and frequency of species in the vegetation away from the vicinity of the smoke stack. Most members of the vegetation possessed smaller leaves with the exception of few which had medium sized leaves. The broad leaved plants were totally absent in this areas.

Sinha (1973) reported that the average dust discharged into the atmosphere through several cement kiln chimneys amounted to 1.25 million tonnes/year into the atmosphere. A part of the fine powders as mentioned above finally escapes to the air through chimneys and pollutes the atmosphere which may retard the growth of the vegetation.

Bohne (1974) stated that dust from cement works contains 30 to 40% lime and 15 to 20% silicic acid, which harmed the growth of trees.

Parthasarathy *et al.* (1975) conducted experiment in the fields nearby a cement factory. Cement dust deposit varied with the distance from the kiln. It was observed that fourth and fifth leaf of maize crop had comparatively more dust than the first three leaves from the top. The cement dust deposited plants showed suppression in most of the characters like height, leaf size, number and size of cobs, when compared to plants in nonpolluted fields.

Toth and Hanus (1975) concluded from pot culture and field experiments on soil polluted with dust from cemen works that the above ground plant dry matter of oat and the tuber starch content of potatoes were markedly decreased by polluted soil as compared to control on unpolluted soil. Pollution increased the contents of SiO_2 and CaO in the grain dry matter of oats and CaO and MgO in the tuber dry matter of potatoes.

Klinosek (1976) studied the effect of cement dust on seven species growing at various distances from a cement works. It was observed that Cornus mas and Crataegus monogyna were sensitive to dust pollution. Whereas Tamari pentandra, Cerasus (Prunus) avium, Pinus nigra, Populus robusta and P.alba showed tolerance.

Rhoades (1976) observed severe foliar chlorosis, leaf scorching accompanying branch die-back and mortali of Q.prinus, Q.velutina, Q.rubra, Q.coccinea and Q.alba growing under cement dust polluted environment from 1903 to 1940. It was concluded that acid loving species such as Q.prinus were unable to obtain certain essential nutrients as soil pH values in the affected area were abnormally hig

Oblisami et al. (1978) reported that cement kiln dust deposit varied with the orientation of the leaves and maximum dust deposition was observed in the middle group leaves. The plant height, number of leaves per plant and number of bolls per plant were lower in the polluted cotton plants when compared to those of the non-polluted plants. The cement kiln dust pollution seems to affect the photosynthetic process and nutrient uptake of the plants whereby, interfering the growth and production potential.

Hanus and Toth (1979) carried out chemical and chromatographic analysis of sugar in bean (Phaseolus vulgaris) dusted in the 1st stage of development with a cement factory dust and showed that the contents of reducing and total sugars were lower than in undusted control plants. Dry matter content of the leaves, but not the stems, of dusted plants was higher than that of the control plants. Dusted plants showed high cellulose and low starch contents as compared to control plants.

Borka (1980) applied cement dust to the leaves of Helianthus annuus var. GK-70 in quantities based on the emission values of the Duna cement kiln. Dust applied at 30 g/m^2 per month damaged crop slightly. After 130 days, height was reduced by 4.5% as compared to control plants. At 100 days, the percentage reductions were found to be in total leaf area by 3.1%; stomatal resistance by 10%; photosynthetic pigment content by 5.7%, respiration rate by 10.9% and catalase activity by 22% in dusted plants.

Singh and Rao (1980) reported that the cement dust deposited on plants interfered with their growth and development leading to reductions in their several morphological characters like length and number of roots, leaves, shoots and ears. The photosynthetic area and grain setting of affected plants were also remarkably reduced. These changes were negatively correlated with the distance from the source of dust emission.

Borka (1981) studied the effect of cement kiln dust on maize plant. It was noted that in consequence of the continuous pollution, the leaves became evenly covered with cement. As a result, the height of the plant was decreased. The initial small degree of pollution had a possitive effect on the growth rate of the leaf blade, but the development of the cement crust had a negative effect. The dust layer blocked stomata thus, causing disturbances in the carbon assimilation and in the heat and water regimes of the plant.

Borka et al.(1981) reported that plants of winter wheat cv. Bezostaya I, Bankuti and Novin 10, grown in pots or in field plots were treated with 7 or 30 g cement dust/m^2 leaf surface every 3 days throughout the growing season. Pollution caused reduction in plant height, dry matter accumulation and ear size while some ears became deformed. Effects tended to increase with increased rate of applied dust.

Borka (1985) noted delayed growth of pea plants grown in presence of loose cement dust by 4-6 days when compared with control plants. There was a delay in flowering while fertilization phase was shortened. Contaminated plants were taller and showed sharp decrease in the intensity of metabolic degradation processes including catalase enzyme activity and respiration intensity.

Jerath et al. (1985) studied the effect of cement dust pollution on vegetation growing in the vicinity of a cement factory. Psemazeton sp.; Sassurea sp. and Veronica sp. showed highest sensitivity to cement dust pollution. Amongst the tree species, flowering and fruiting was conspicuously absent or reduced on the side facing the factory. The height of the plants was also decreased with the decrease in distance from the factory.

Anda (1986) measured changes in the radiation balance (albedo) of maize polluted with cement dust. It was observed that radiation intake of polluted plants was increased, and this increased plant temperature and evapotranspiration. Higher radiation values did not have a positive effect on dry matter production.

Borka (1986) reported that the floating dust from the cement works settled mainly on the leaves of the winter barley, forming a more or less continuous cement crust under the influence of moisture. Interaction of frequent small quantities of precipitation and alkaline cement dust resulted in partial epidermis injuries to the young leaves. The generative organs of dust contaminated plants showed unfavourable development and growth; the number of flowers and spikelets in the spike became smaller.

Sai *et al.* (1987) reported that the cement dust significantly affected the height of Arhar (*Cajanus cajan*), wheat (*Triticum aestivum*) and Alsi (*Linum usitatissimum*) in the vicinity of cement factory.

Agrawal *et al.* (1988) reported foliar injury symptoms in form of chlorosis, necrosis and crust formation in most of the plant species growing upto 2 km^2 area around the cement factory. However, in case of *Anisomelus avata*, *Calotropis procera*, *Mukia seabrella* and *Ocium* sp.; no such symptoms were observed. The dust deposited on leaves gradually decreased at increasing distance from cement plant. Maximum dust deposition of 9.60 gm^{-2} leaf area on *Mangifera indica* and a minimum of 4.30 gm^{-2} leaf area on *Ocium* sp. were recorded at a distance of 0.1 km NE from the cement factory.

Gunamani *et al.* (1989) reported that the cement kiln exhaust affected the morphology and anatomy of plants. The deleterious effects of the dust on the morphology of the leaves included reduction in leaf size, necrosis, change of colour, curling of leaves etc. Anatomically, the leaf thickness was altered. The epidermal cell wall was modified . The epidermal cell number was increased. However, the cell size was decreased.

Swaminathan et al.(1989) observed retardation in plant growth, necrosis, cracks, injuries and border effect of trunks, branches and leaves of some plants due to cement dust deposition. The effects included plugging of stomatal apertures, closure of stomata, deformation of guard cells and malformation of subsidiary cells. These effects in turn reduced the rate of photosynthesis, carbohydrate content and rate of respiration which led to retardation in growth of the plants.

Prasad and Inamdar (1990) studied the effect of cement kiln dust pollution on black gram (Vigna mungo). The cement kiln dust pollution decreased height and number and size of flowers.

Gunamani and Arjuman (1991) observed that the flora present in the vicinity of a cement factory was heavily deposited by the kiln exhaust dust. The morphology and anotomy of the plants were affected by the cement kiln dust. The aerial parts of all the plants studied were fully coated with the dust. The deleterious effects of the dust on the morphology of the leaves were expressed by the reduction in size of the leaf, necrosis, damaged leaf margin, change of colour, curling of leaves etc.

Prasad and Inamdar (1991) reported effects of cement kiln dust pollution on growth characters and yield in Vigna aconitifolia, V.radiata and V.unguiculata. Polluted plants of V.aconitifolia exhibited 50% reduction in shoot length. Phytomass was reduced upto 71.78% in V.unguiculata while root/shoot ratio was increased upto 26.43%. The number of fruits was reduced upto 63.28% in V.radiata.

Anonymous (1992) studied the effect of graded doses (1 g, 3 g and 5 g/m^2) of cement dusting on cotton plants daily for 50 days. Cement dusting affected physiological characters like dry matter production, photosynthesis, leaf area, LAI, RGR and NAR significantly.

Anonymous (1992) reported that the continuous cement dusting at the rate of 1 to5 g/m^2 daily for 40 days on soybean crop significantly reduced the plant height by 9 to 20%, leaf number by 13 to 32%, chlorophyll content 5 to 12%; leaf area by 7 to 11%, 13 to 19% and 22 to 27%; dry matter production by 4 to 28%, LAR by 4 to 7%; 6 to 12% and 8 to 18%, LAI by 12 to 24%, specific leaf weight by 9 to 19%, RGR by 23, 36 and 46%.

Satao et al.(1993) reported that cement dust pollution (0, 4, 7 and 10 $g/m^2/day$) significantly reduced height, number of branches and dry weight per plant. The reduction in height of cotton AHH 468 was 1.94, 5.65, 8.17% and in AKH-4, 4.3, 8.56 and 13.74% over control, respectively. The reduction in number of branches per plant was 4.39, 11.27, 22.04 % in AHH-468 and 11.95, 15.54, 38.98% in AKH-4 over control. Similarly, reduction in dry weight per plant was 10.98, 18.82, 22.95% in AHH-468 and 12.35, 15.66, 29.21% in AKH-4 over control, respectively. The reduction was of higher magnitude with increased rate of cement dust pollution.

2.4 Effect of Dust Pollution on Physiological Parameters

2.4.1 Effect of dust pollution on chlorophyll content

Ionescu and Neema (1974) reported that in an area polluted by dust from cement and ceramic works, the chlorophyll contents of leaves of wheat and maize were lower than that in an unpolluted area.

Borka (1980) noted relatively lower effects of cement dust applied at 30 g/m^2 per month on Helianthus annuus cv. GK-70. At 100 days, the reduction in photosynthetic pigment content was observed to the extent of 5.7%.

Lal and Ambasht (1980) observed thick deposition of cement dust on upper surface of leaves of P. guayava plants, growing near the cement factory. The concentrations of chlorophyll 'a' and 'b', total chlorophyll, ratio of a:b chlorophylls and carotenoids were always greater in dusted leaves.

Singh (1980) treated wheat plants with cement and nitrogen dioxide (NO_2) alone and in combination between the age of 20 and 100 days. The results revealed that cement dust and NO_2 applied alone and in combination caused measurable reduction in chlorophyll content. Wheat crop growing at polluted sites showed lower chlorophyll contents (Singh and Rao, 1980). Singh and Rao (1981) confirmed above observation by dusting wheat plants @ 7.0 g/m^2 cement dust/day for 60 days. Borka (1986) also reported similar results in winter barley and in maize by Pande and Simba (1990). However, Borka *et al.* (1981) observed increased chlorophyll content in winter wheat (cv. Bezostaja I, Bankuti and Novin-10 treated with 7 or 30 g cement dust/m^2 leaf surface) and in maize (Borka, 1981). Similar result were reported by Pawar *et al.* (1982).

Krishnamurthy and Rajachidambaram (1986) recorded 56-68% reduction in leaf chlorophyll in cement dust coated leaves of *Borassus flabellifer*, *Curcuma longa*, coconut, tamarind.

Sai *et al.* (1987) determined cement dust deposits and chlorophyll content on leaves of *Ficus bengalensis* and *Mangifera indica* trees and reported negative (non-significant) correlation along the penalization gradient (down wind direction).

Agrawal *et al.*(1988) observed decrease in chlorophyll content by 52% in *Cassia tora* and 21.37% in *Calotropis procera* near the vicinity of cement factory.

Prasad and Inamdar (1990) studied the effect of cement kiln dust pollution on black gram (*Vigna mungo*) and found decrease in chlorophyll content. Reduction in chlorophyll content of leaves due to cement dust application have been reported by Prasad and Inamdar (1990) in pea (*Pisum sativum*); Prasad *et al.*(1991) in Arhar(*Cajanus cajan*) and Anonymus (1992) in soybean.

Shukla *et al.* (1990) treated *Brassica campestris* L. var. G-320 with cement dust at the rate of 3, 5 and 7 g/m^2/day for 90 days. Treated plants showed a consistent reduction in photosynthetic pigments over control plants.

2.4.2 Effect of dust pollution on leaf temperature :

Eller (1977) reported rise in temperature of dusty leaves of bush *Rhododendron catawbiense* Michx cv. by 2 to 4°C when compared with clean leaves. The increased leaf temperature by road dust strongly influenced net photosynthesis and productivity.

Maier *et al.*(1979) reported that the woody plants (Norway spruce foliage) and shrubs (hazel) at three sites at increasing distance from the cement factory, directly outside the factory, and heavily contaminated with dust increased the leaf temperature of broad leaves and herbs by 1.4°C.

2.4.3 Effect of dust pollution on transpiration :

Gale and Easton (1979) observed small effects of limestone dust in reducing transpiration of *Xanthium strumarium* leaves during the summer season.

Maier *et al.*(1979) stated that the woody plants (Norway spruce foliage) and shrubs (hazel) at three sites at increasing distance from the cement factory, directly outside the factory and heavily contaminated with dust and moderately contaminated forest margin, the transpiration of broad leaves showed a peak earlier in the day (11 a.m.) and their leaf saturation deficit was higher than slightly contaminated forest cleaning.

Singh and Rao (1981) reported that the wheat plants dusted with 7 g/m^2 cement dust a day for 60 days reduced the transpiration rates significantly. Dust from quarries, cement factories and road traffic were found to affect transpiration process in agricultural and horticultural crops like grassland, health lands, trees and wood lands, arctic bryophyte and lichen communities(Farmer, 1993).

2.4.4 Effect of dust pollution on photosynthesis :

Photosynthesis is a vital process in autotrophs and has direct effect on growth and productivity. Cement kiln dust pollution was found to affect photosynthetic process whereby, interfering the growth and production potential of the plant system (Oblisami et al., 1978). Maier et al. (1979) reported that photosynthesis in hazel was lower in shrubs (hazel) directly outside the factory and heavily contaminated with dust than slightly contaminated forest cleaning.

Gale and Easton (1979) measured the dust accumulation on the leaves of Xanthium strumarium during the summer season and noted small effect in reducing photosynthesis. However, Borka et al. (1981) demonstrated that plants of winter wheat cv. Bezostaja I, Bankuti and Novin 10 treated with 7 or 30 g cement dust/m^2 leaf surface showed reduced photosynthesis.

Taniyama et al. (1981) observed that in rice cv. Koshihikari, daily application of 1, 2 or 5 g cement dust/m^2 decreased rate of photosynthesis to 6.65, 6.81 and 6.11 $mg/dm^2/h$, respectively, as compared with 8.76 $mg/dm^2/h$ in the untreated control. Inhibitory effects of cement dust pollution on rate of photosynthesis have also been reported by Prasad and Inamdar (1990) in Vigna mungo and Anonymus (1992) in cotton.

Krishnamurthy and Rajachidambaram (1986) recorded the reduction in photosynthetic rate in cement dust coated leaves of Borassus flabellifer, Curcuma longa, coconut, tamarind. While Swaminathan et al. (1989) reported reduced rate of photosynthesis, carbohydrate content in Azadirachta indica, *Cocos nucifera*, *Mangifera indica*, *Prosopis cineraria*, *Tamarindus indica* due to dust pollution. Similerly dust from quarries, cement factories and road traffic was reported to affect photosynthesis process in agricultural and horticultural crops, like grasslands, health lands, trees and woodlands, aretic bryophyte and lichen communities (Farmer, 1993).

2.4.5 Effect of dust pollution on respiration :

Swaminathan *et al*. (1989) noted that the cement factory kiln exhaust reduced the rate of dark respiration in *Azadirachta indica*, *Cocos nucifera*, *Mangifera indica*, *Prosopis cineraria*, *Tamarindus indica*. By and large, dusts from quarries, cement factories and road traffic affect the respiration process in agricultural and horticultural crops, aretic bryophyte and lichen communities (Farmer, 1993).

2.4.6 Effect of dust pollution on Biomass production :

Singh (1980) stated that wheat plants in 1 m^2 plots were treated with cement and nitrogen dioxide (NO_2) alone and in combination between the age of 20 and 100 days. The results revealed that cement dust and NO_2 applied alone and in combination caused measurable reduction in biomass accumulation.

Singh and Rao (1980) analysed the cement dust polluted samples with respect to phytomass accumulation and observed that plant closer to the cement factory had reduced accumulation of phytomass.

Singh and Rao (1981) reported that the wheat plants dusted with 7 g/m^2 cement dust a day for 60 days showed significantly reduced productivity.

Ambrust (1986) reported that the reduction in phytomass was not only due to reduced photosynthesis, but also due to increased dark respiration.

Prasad and Inamdar (1990) studied the effect of cement kiln dust pollution on black gram by comparing plants of polluted as well as non-polluted areas. Due to cement kiln dust accumulation on exposed parts of the plants, there was a decrease in phytomass and net primary productivity.

Shukla _et al_. (1990) dusted plants of _Brassica campestris_ L.var. G-320 with cement dusts, at rates of 3, 5, 7 g/m^2/day for 90 days. Treated plant showed a consistent reduction in growth, photosynthetic pigments, yield and oil content over control. The overall phytomass of treated plants was significantly decreased, the maximum reduction being 64.8% in 7 g/m^2 followed by 5 g/m^2 (55.3%) and 3 g/m^2(43.69%) at 60th day.

Prasad and Inamdar (1991) studied the effect of cement kiln dust pollution on _Vigna aconitifolia_, _V.radiata_ and _V.unguiculata_ and observed that phytomass was reduced upto 71.78% in _V. unguiculata_. The number of fruits reduced upto 63.28% in _V.radiata_.

Prasad _et al_. (1991) studied the effect of cement kiln dust pollution on _Cajanus cajan_ and showed reduction in growth, phytomass and net primary productivity.

* * *

CHAPTER III

MATERIALS AND METHODS

The investigations reported herein were carried out in the field of Department of Botany, Punjabrao Krishi Vidyapeeth, Akola, located at 307.415 meters altitude, $22^{0}41'$ latitude and $77^{0}02'$ E longitude, during rabi seasons of 1987-88 and 1988-89.

3.1 Experimental Details

		1987-88	1988-89
3.1.1	Design of experiment	Factorial Randomised Block Design	Factorial Randomised Block Design
3.1.2	No.of replications	4	4
3.1.3	No.of treatments	8	12
	a) Main factor(dusts)	2 i) Soil ii) Cement	3 i) Soil ii) Cement iii) Kiln dust
	b) Sub-factors(doses)	4 i) 0.0 g/m^2 ii) 1.0 g/m^2 iii) 3.0 g/m^2 iv) 5.0 g/m^2	4 i) 0.0 g/m^2 ii) 1.0 g/m^2 iii) 3.0 g/m^2 iv) 5.0 g/m^2
3.1.4	Plot size	1.8 x 2 m	1.8 x 2 m
3.1.5	Spacing	22.5 x 2.5 cm	22.5 x 2.5 cm
3.1.6	Methods of sowing	Drilling	Drilling
3.1.7	Date of sowing	24.11.87	21.11.88
3.1.8	Seed rate	100 kg/ha	100 kg/ha
3.1.9	Crop	Wheat variety Kalyan Sona	

3.2 Sowing

Seed was treated with Agroson G.N. at the rate of 2.5 g/kg of seed before sowing. Fertilizers were applied @ 100 kg N + 50 kg P_2O_5 + 50 kg K_2O/ha to gross plots. Half N and complete doses of P_2O_5 and K_2O were given as a basal dose while remaining N was applied one month later.

3.3 Irrigations

A uniform pre-sowing irrigation was given to all plots during both the years of experimentation. In all, crop received seven to eight irrigations as and when required (including critical stages of growth). While irrigating the crop, care was taken to supply water uniformly and with slow speed.

3.4 Plant Protection Measures

As preventive measures, one endosulphan spray was given at early stage (30 DAS) and Diethane Z-78 spray was given during earhead emergence stage.

3.5 Application of Dust

For dusting the plunger duster was used. At the time of dusting, crop was covered with musline cloth tents (2 x 2 x 1.75 m) for effecting uniform load of dusts in air. The dusting was started 30 days after sowing. Crop was dusted in the evening at every alternate day.

Dusting was continued till the harvest of crop. The tents were removed in the morning.

3.6 Observations

Observations on following characters were recorded during the ontogeny of crop. The methods used are described below.

3.6.1 Plant height (cm) :

Plant height was recorded at the time of harvest. The height was measured on randomly selected five plants in each plot in cm from the base of the plant to the top of the earhead.

3.6.2 Tiller count :

Total number of tillers, exclusive of main shoot per plant were counted periodically on the five plants selected from each plot.

3.6.3 Leaf area per plant :

To determine the area of leaves, five plants were selected at random from each plot. The green leaves were separated and leaf area was measured on automatic leaf area meter (model AAM 7, Japan).

3.6.4 Leaf area index (LAI) :

LAI represents the ratio of leaf area to the land area. The leaf area indices were worked out from the data on leaf area recorded at various growth stages and land area provided to a plant by using the formula given by Watson (1947).

$$LAI = \frac{\text{leaf area } (m^2)}{\text{land area } (m^2)}$$

3.6.5 Dry matter production :

In order to study the effect of dusts on dry matte production, plants were sampled from one meter row leng discarding root portion.

In 1987-88 plant samples were taken on 25 DAS and in 1988-89 the plant samples were taken on 30 DAS. Periodic samples were taken at 15 days interval in both the seasons of experimentation. The samples were kept in brown paper bags and then dried in electric oven at 70° The last constant weight was recorded as dry matter weight From these weights, dry matter produced per plant was determined.

3.7 Physiological Parameters

a) Crop growth rate (CGR)
b) Relative growth rate (RGR)
c) Net assimilation rate(NAR)

Above growth parameters were determined by using following formulae

3.7.1 Crop growth rate (CGR):

Crop growth rate gives rate of dry matter increase in per unit time. It is generally expressed as g/day. Formula used for finding out CGR (Watson,1958) was as follows :

$$CGR(g/day) = \frac{W_2 - W_1}{t_2 - t_1}$$

Where W_2 and W_1 represents the total dry matter produced at t_2 and t_1 time interval (days).

3.7.2 Relative growth rate (RGR) :

Blackman (1919) stated that the increase in dry matter of a plant is a process of continuous compound interest; wherein the increment at any interval adds to the capital for subsequent growth. The rate of increment is known as relative growth rate. For calculating RGR for formula given by Fisher (1921) was used.

$$RGR(g/g/day) = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$

Where W_2 and W_1 are weights of total dry matter per plant at the time t_2 and t_1 (DAS) respectively. It is expressed in g/g/day.

3.7.3 Net assimilation rate (NAR) :

Gregory (1926) used the term "Net assimilation rate" (NAR). Williams (1946) provided a formula for estimating mean NAR over a period of time.

$$NAR(g/dm^2/day = \frac{W_2-W_1}{t_2-t_1} \times \frac{Loge\ LA_2-Loge\ LA_1}{LA_2-LA_1}$$

Where LA_1 and LA_2 represent leaf area (dm^2) and W_1 and W_2 as dry weight of plant (g) at time interval t_1 and t_2(days) respectively. It is expressed in $g/dm^2/day$.

3.7.4 Rate of Transpiration :

Transpiration rate of the leaves was measured by the cobalt chloride paper (Mayer and Anderson, 1955) by following formula:

$$G\ (g/dm^2/second) = \frac{3600X}{T}$$

Where,

X = Grams of water vapour required to change 1 dm^2 of cobalt chloride paper from blue to pink colour.

T = Observed time of colour change in second on leaf

3.8 Yield Contributing Characters

3.8.1 Thousand grain weight :

Composite samples of grain from each plot yield was drawn to count one thousand grains. These counted grains were weighed on chemical balance to record test weight.

3.8.2 Number of grains per earhead :

The earheads obtained from five randomly selected plants were threshed seperately and total number of grains obtained were counted. From this data number of grains per earhead was calculated.

3.8.3 Number of earheads/m^2 :

The earheads obtained from one m^2 plot were counted to record number of earheads/m^2.

3.8.4 Number of spikelet per earhead :

Five randomly selected earhead (main culm) were used to count total number of spikelets. Data obtained was used to determine mean number of spikelets/earhead/plant.

3.9 Plant Yield

3.9.1 Biological yield :

Produce of each net plot was tied in bundles and were allowed to dry in respective plots for eight days. After thorough sun drying, the weight of total produce (grain + straw) from each plot was recorded (g).

3.9.2 Grain yield :

Eight days after harvest, the produce from each plot was threshed with manual labour. Grains were separated and cleaned. Grains of each plot were again dried in hot sun for two days and grain weights of all plots were recorded(g)

3.9.3 Harvest index :

Harvest index was worked out by the following formula.

$$\text{Harvest index}(\%) = \frac{\text{Grain yield/plot (g)}}{\text{Biological yield/plot(g)}} \times 100$$

3.10 Chemical Analysis

3.10.1 Total chlorophyll content (Fresh weight basis):

Total chlorophyll content was determined spectrophotometrically using the method given by Yoshida *et al.*(1971). The total chlorophyll (mg/g fresh weight) was computed by the formula given below :

$$\text{Total Chlorophyll(mg/g) tissue} = \frac{D\ 652 \times 1000}{34.5} \times \frac{V}{1000 \times W}$$

Where,

D = Optical density at 652 mμ

V = Final volume

W = Fresh weight of sample in g.

3.11 Meteorological Data

The meteorological data on rainfall, maximum and minimum temperature, humidity were obtained from the Meteorology Observatory, Department of Agronomy, Punjabrao Krishi Vidyapeeth, Akola and are presented in Appendix III.

CHAPTER IV

RESULT

The effects of dust pollutions on growth, development and yield of wheat are presented in this chapter.

4.1 Effect of Dust Pollution on Final Height

Height is a measure of general growth of plant. It is being affected by large number of internal and external factors. In order to assess the effect of dust pollution on growth, final height(cm) was measured at maturity. Data are presented in Table 1.

Data presented in Table 1 revealed that height of wheat during 1987-88 was significantly affected by dust applications. Amongst dusts, cement dust showed significant reduction in plant height. During 1988-89 regarding the effects on height, differences amongst the main factors, viz season, cement, soil and kiln dusts were not significant.

The effects of graded concentrations of dusts applications on height were significant during both the seasons. The height was significantly reduced at all levels of dust applications over control. Height was gradually decreased as the doses of dust applications were increased. Minimum height was observed at 5.0 g dust

Table 1. Effect of dust pollution on final height (cm) of wheat

Concentration / Treatments	(1987-88) 0	1	3	5	Mean	(1988-89) 0	1	3	5	Mean
Soil dust	84.96	81.20	77.80	76.80	80.19	85.12	82.47	80.00	76.10	80.92
Cement dust	84.96	81.03	75.20	71.60	78.20	87.50	79.82	75.27	73.65	79.06
Kiln dust	-	-	-	-	-	85.75	81.15	79.20	74.40	80.12
Mean	84.96	81.11	76.50	74.20		86.12	81.15	78.15	74.71	
	T	C	TxC			T	C	TxC		
'F' test	Sig.	Sig.	NS			NS	Sig.	NS		
SE(m) ±	0.65	0.92	1.30			0.57	0.66	1.14		
C.D.(5%)	1.98	2.80	-			-	1.89	-		
C.V. %	2.85					2.85				

dust application (74.20 and 74.71 cm).

The interaction effects were not significant. These results indicated that irrespective of source of dusts, dust depositions on plants retarded wheat growth in similar manner.

4.2 Effect of Dust Pollution on Leaf Area/Plant

Photosynthetic efficiency of green plants is greatly influenced by leaf area exposed to light. It has direct relationship with productivity. Periodic observations on leaf area as affected by dust applications were recorded and are presented in Table 2.

Data presented in Table 2 revealed that during the year 1987-88, cement dust application showed significant reduction in leaf area/plant over soil dust at 40 DAS. At 25, 55, 70, 85 and 100 DAS, effects of soil dust and cement dusts were at par. During 1988-89, cement and kiln dust showed significant reduction in leaf area over soil dust at 45 DAS. At remaining stages, effects of all dusts applications were at par.

The effects of levels of dusts applications on leaf area/plant were significant during both the seasons at all stages except at 100 DAS during 1987-88. Maximum leaf area(23.85 and 23.55 dm^2) was noted in control plants during both the seasons. The leaf area/plant was significantly

Table 2. Effect of dust pollution on leaf area/plant (dm^2).

Treatments	Days after sowing (1987-88)						Days after sowing (1988-89)				
	25	40	55	70	85	100	30	45	60	75	90
Soil dust	3.22	8.06	12.33	20.15	27.08	23.14	6.40	10.21	18.25	25.99	22.85
Cement dust	3.03	7.74	12.03	19.88	26.81	22.88	6.16	9.87	18.10	25.02	22.64
Kiln dust	-	-	-	-	-	-	6.13	9.74	18.08	25.00	22.40
'F' test	NS	Sig.	NS	NS	NS	NS	NS	Sig.	NS	NS	NS
SE(m)±	0.10	0.10	0.12	0.27	0.15	0.46	0.18	0.10	0.12	0.38	0.24
C.D.(5%)	-	0.30	-	-	-	-	-	0.29	-	-	-
0	3.65	8.68	12.89	20.83	27.77	23.85	7.08	10.91	19.20	26.13	23.55
1	3.43	8.21	12.57	20.43	27.36	23.42	6.26	10.15	18.17	25.36	22.86
3	2.99	7.75	11.89	19.73	26.67	22.72	5.97	9.67	17.85	25.77	22.34
5	2.42	6.96	11.38	19.06	26.00	22.06	5.58	9.04	17.35	24.07	21.76
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	NS	Sig.	Sig.	Sig.	Sig.	Sig.
SE(m)±	0.15	0.14	0.17	0.38	0.21	0.65	0.10	0.12	0.14	0.44	0.32
C.D.(5%)	0.44	0.42	0.53	1.16	0.42	-	0.30	0.33	0.41	1.26	0.91
C.V.%	11.38	4.30	3.50	4.66	1.91	0.79	5.71	4.04	2.70	5.98	1.84
Test for Interaction											
'F' test	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SE(m)±	0.21	0.20	0.25	0.54	0.30	0.91	0.18	0.20	0.25	0.76	0.47
C.D.(5%)	-	-	-	-	-	-	-	-	-	-	-

reduced at 3 g/m^2 (22.72 and 22.34 dm^2) and 5 g/m^2 (22.06 and 21.76 dm^2) levels of dusts applications respectively over control. 1 g/m^2 (22.86 dm^2) recorded significantly lower leaf area/plant during 1988-89 at 45 DAS over control. At rest of the stages, mean leaf area was not significant. In general, leaf area/plant gradually decreased as the doses of dust applications increased. Minimum leaf area/plant was observed at 5.0 g/m^2 dose.

The interaction effects were not significant.

4.3 Effect of Dust Pollution on Leaf Area Index (LAI)

Data presented in Table-3 showed non-significant differences among dusts on LAI at all the stages of growth during both the seasons. LAI gradually increased upto 85 DAS and 75 DAS and declined at later stages during 1987-88 and 1988-89, respectively.

The levels of dust applications showed significant reduction in LAI over control during both the seasons. The mean LAI in 1 g/m^2 treatment was at par with control. However, 3 g and 5 g/m^2 dust applications showed significant reduction in LAI over control, upto 70 DAS where as LAI at 85 and 100 DAS were at par in all treatments during 1987-88. Significant reduction in LAI was observed in 5 g/m^2 dust application over 3 g/m^2. During 1988-89, leaf area index amongst the treatments at 30 DAS was at par. However, it differed significantly at remaining stages of observations.

Table 3. Effect of dust pollution on leaf area index (LAI)

Treatments	Days after sowing (1987-88)						Days after sowing (1988-89)				
	25	40	55	70	85	100	30	45	60	75	90
Soil dust	0.51	1.29	1.97	3.22	4.33	3.70	1.02	1.64	2.93	4.06	3.66
Cement dust	0.48	1.27	1.92	3.18	4.29	3.66	0.98	1.56	2.89	3.99	3.62
Kiln dust	-	-	-	-	-	-	0.95	1.54	2.89	3.97	3.58
'F' test	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SE(m) ±	0.02	0.03	0.04	0.04	0.06	0.07	0.04	0.04	0.04	0.04	0.04
C.D.(5%)	-	-	-	-	-	-	-	-	-	-	-
0	0.58	1.42	2.07	3.33	4.44	3.82	1.09	1.69	3.05	4.15	3.77
1	0.54	1.35	2.01	3.26	4.37	3.75	1.01	1.62	2.92	4.06	3.66
3	0.48	1.24	1.90	3.15	4.26	3.64	0.96	1.55	2.86	3.97	3.57
5	0.39	1.11	1.82	3.05	4.15	3.53	0.89	1.45	2.78	3.85	3.48
'F' test	Sig.	Sig.	Sig.	Sig.	NS	NS	NS	Sig.	Sig.	Sig.	Sig.
SE(m) ±	0.02	0.04	0.06	0.06	0.08	0.10	0.05	0.04	0.05	0.04	0.04
C.D.(5%)	0.07	0.11	0.18	0.19	-	-	-	0.12	0.13	0.13	0.13
C.V.%	10.64	6.98	7.41	4.67	4.65	6.87	16.93	9.41	5.41	3.67	4.19
Test for Interaction											
'F' test	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SE(m) ±	0.03	0.05	0.04	0.09	0.12	0.15	0.08	0.07	0.08	0.07	0.08
C.D.(5%)	-	-	-	-	-	-	-	-	-	-	-

The levels of dust applications showed similar trend in 88-89 like that 1987-88. Data thus, revealed that mean LAI gradually decreased with increased doses of dust applications.

The interaction effects were non-significant during both seasons.

4.4 Effect of Dust Pollution on Number of Tillers/m Row Length

Production of tillers in cereals is a unique character which increases the LAI and ear number. Ear number and LAI have direct effects on grain yield. Therefore, observations on number of tillers/m row length were recorded. Data are presented in Table 4.

Inspection of table 4(A) revealed non-significant effects of dusts on tiller production at all stages during 1987-88. During the year, 1988-89, at 30 and 45 DAS, mean tiller number/m row length was at par in cement and soil dust applications. However, significant differences in tiller production were recorded at 60, 75 and 90 DAS. At 60 days (1988-89) kiln dust showed significantly lower tiller number than soil dust. Mean tiller number in soil and cement dusts were at par. At 75 and 90 DAS cement and kiln dust applications had significantly lower tiller number than soil dust application. Mean tiller number in cement and kiln dust applications were at par.

Table 4(A). Effect of dust pollution on number of tillers/m row length.

Treatment	Days after sowing (1987-88)					Days after sowing (1988-89)				
	40	55	70	85	100	30	45	60	75	90
Soil dust	39.00	42.08	44.41	43.16	43.08	33.81	37.56	40.06	41.56	41.00
Cement dust	37.66	41.91	43.41	42.50	42.33	33.06	37.50	39.06	39.81	39.06
Kiln dust	-	-	-	-	-	33.93	37.87	38.56	39.25	39.25
'F' test	NS	NS	NS	NS	NS	NS	NS	Sig.	Sig.	Sig.
SE(m)±	0.98	0.85	0.80	0.78	0.86	0.41	0.47	0.40	0.34	0.36
C.D.(5%)	-	-	-	-	-	-	-	1.14	0.96	1.05
0	44.00	48.50	49.83	49.33	49.16	39.08	42.50	44.83	46.67	45.75
1	40.66	44.00	46.16	44.83	44.66	34.41	39.41	40.50	41.25	41.00
3	35.16	39.66	42.33	41.16	41.00	31.91	36.00	37.50	37.83	37.66
5	33.50	35.83	37.33	36.00	36.00	29.00	32.66	34.08	35.08	34.66
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SE(m)±	1.38	1.21	1.13	1.10	1.22	0.47	0.55	0.46	0.39	0.42
C.D.(5%)	4.19	3.66	3.42	3.33	3.69	1.36	1.57	1.31	1.11	1.21
C.V.%	8.84	7.04	6.29	6.27	6.97	4.88	5.01	4.03	3.34	3.66
Test for Interaction										
'F' test	NS	NS	NS	NS	NS	NS	NS	NS	Sig.	NS
SE(m)±	1.96	1.71	1.60	1.55	1.72	0.82	0.94	0.97	0.67	0.73
C.D.(5%)	-	-	-	-	-	-	-	-	1.93	-

The levels of dust applications showed significant effects on tiller production during both the seasons. In general, control (no dust application) produced significantly more tillers/m row length than rest of the levels of dust application. It was also observed that the increase in levels of dust applications decreased tiller number/m row length. Minimum number of tillers were recorded at 5.0 g/m^2 dust application. Rest of the levels showed intermediate tiller number. Tiller number gradually increased upto 85 and 75 DAS during 1987-88, 1988-89, respectively, and was decreased at latter stages of growth.

Interaction effects were not significant at all the stages during 1987-88 and at 30, 45, 60 and 90 DAS during 1988-89, respectively. Significant interaction effects were observed at 75 DAS during 1988-89 which are shown in Table 4(B).

Table 4(B). Effect of dust pollution on number of tillers/m row length

Treatments	1988-89 (75 DAS)				
	0	1	3	5	Mean
Soil dust	47.25	43.50	38.75	36.75	41.56
Cement dust	47.25	40.50	38.00	33.50	39.81
Kiln dust	45.50	39.75	36.75	35.00	39.25
Mean	46.67	41.25	37.83	35.08	
	T		C		TxC
'F' test	Sig.		Sig.		Sig.
SE(m) ±	0.33		0.39		0.67
C.D.(5%)	0.96		1.11		1.92
C.V.%	3.33				

Soil, cement and kiln dust application showed significant reduction in tiller number over control. The tiller number gradually decreased with increased level of application in all the dusts. The minimum and significantl lower tillers/m row length were recorded at 5.0 g/m^2 dust applications in all the dusts used. The significant reduction in tiller number was observed with every increase in level of application in all the dusts. Amongst the dusts at 1.0 g/m^2 and 3.0 g/m^2 levels, minimum and significantly lower tiller number were observed in kiln dust application. Cement dust application also showed lower tiller number/m row length than soil dust. At 3.0 g/m^2 level, cement and soil dust application showed non-significant differences. In general, amongst the dusts, cement and kiln dusts were more detrimental than soil dust.

4.5 Effect of Dust Pollution on Dry Matter Production/m^2

Data presented in Table 5(A) showed non-significant effects of dusts on dry matter production/m^2 at 40, 85 DAS (1987-88) and 45 DAS (1988-89). However, cement dust application significantly reduced dry matter production/m^2 over soil dust application at 25, 55, 70 and 100 DAS during 1987-88, and at 30, 60, 75, 90 DAS during 1989,respectively Dry matter/m^2 in cement and kiln dust applications were at par at 60, 75 and 90 DAS, while kiln dust and soil dust applications were at par at 30 DAS (1988-89).

Table 5(A). Effect of dust pollution on dry matter g/m^2

Treatments	Days after sowing (1987-88)						Days after sowing (1988-89)				
	25	40	55	70	85	100	30	45	60	75	90
Soil dust	76.80	320.08	588.08	933.64	1039.60	1123.40	229.48	433.24	855.72	1026.00	1087.24
Cement dust	71.08	312.04	572.80	906.76	1021.60	1092.80	215.00	420.96	838.72	988.00	1052.72
Kiln dust	-	-	-	-	-	-	224.52	426.00	827.48	974.24	1052.48
'F' test	Sig.	NS	Sig.	Sig.	NS	Sig.	Sig.	NS	Sig.	Sig.	Sig.
SE(m)±	1.00	2.78	4.66	2.86	5.96	4.91	2.49	3.65	5.15	8.40	6.11
C.D.(5%)	3.02	-	14.15	8.66	-	14.89	7.18	-	14.84	24.20	17.59
0	86.00	348.00	627.84	982.40	1107.72	1194.92	257.84	483.88	952.32	1109.64	1181.32
1	84.84	332.72	609.00	952.64	1070.44	1152.04	230.84	452.80	883.00	1037.32	1108.32
3	68.92	306.24	566.60	900.84	1003.92	1080.52	212.60	398.08	790.32	948.32	1009.00
5	56.04	277.32	518.32	844.92	940.32	1005.00	190.72	372.16	737.00	889.00	958.00
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SE(m)±	1.41	3.94	6.60	4.04	8.43	6.94	2.88	4.21	5.95	9.70	7.06
C.D.(5%)	4.27	11.94	20.02	12.25	25.57	21.06	8.30	12.13	17.14	27.94	20.32
C.V. %	18.65	12.20	11.13	4.30	8.00	6.14	17.90	13.67	9.81	13.50	9.19
Test for Interaction											
'F' test	NS	NS	NS	NS	NS	NS	NS	Sig.	NS	NS	NS
SE(m)±	0.50	1.39	2.33	1.43	2.98	2.45	1.25	1.82	2.58	4.20	3.06
C.D.(5%)	-	-	-	-	-	-	-		-	-	-

The effects of graded concentrations of dust applications on dry matter/m^2 were significant during both the seasons. The dry matter/m^2 was significantly reduced at 3 g/m^2 and 5 g/m^2 levels of dust applications over control. 1 g/m^2 level also had significantly lower dry matter/m^2 at 40, 70, 85, 100 DAS than control during 1987-88, whereas all levels of dust applications showed significant reduction in dry matter/m^2 over control during 1988-89. Maximum dry matter/m^2 (1194.92 and 1181.12 g) was observed in control (no dust application). The dry matter/m^2 gradually decreased as the doses of dust applications were increased. Minimum dry matter/m^2 was observed at 5.0 g/m^2 dust application. Rest of the treatments had intermediate dry matter.

Interaction effects were significant only at 45 DAS. The data are shown in Table 5(B).

Table 5(B). Effect of dust pollution on dry matter production g/m^2 45 DAS.

Treatments	1988-89				Mean
	0	1	3	5	
Soil dust	484.28	468.28	403.92	375.66	433.24
Cement dust	483.44	455.80	385.48	359.08	420.96
Kiln dust	482.92	434.32	404.84	381.88	426.00
Mean	483.88	452.80	398.08	372.16	

	T	C	T x C
F test	NS	Sig.	Sig.
SE(m) ±	3.65	4.21	7.29
C.D. at 5%	-	12.13	21.00
C.V. %	13.67		

It is observed that mean dry matter production/m^2 at control and 1.0 g/m^2(soil) were at par. However, higher levels of application (3.0 and 5.0 g/m^2) significantly reduced dry matter/m^2 over control and 1.0 g/m^2 level. In cement and kiln dusts, the dry matter/m^2 was significantly decreased by every increased level of dust application. Maximum dry matter was observed in control and minimum at 5.0 g/m^2 level. Amongst dust kiln dust application at 1.0 g/m^2 level showed significantly lower dry matter than soil and cement dust applications. The soil dust, and cement dusts were at par at all the levels. While soil dust, cement dust and kiln dust were at par at 3.0 g/m^2 level. At 5.0 g/m^2 level, cement dust application was at par with soil dust application and recorded significantly lower dry matter/m^2 than kiln dust application.

4.6 Effect of Dust Pollution on Crop Growth Rate

Data presented in Table 6 indicated that crop growth rate of wheat under soil and cement dust pollution (1987-88) showed a gradual increase upto 55-70 DAS period. CGR sharply declined at 70-85 DAS. This decrease continued upto 85-100 DAS. The effects of soil and cement dust applications on CGR were not significant in 1987-88. During the year 1988-89, soil, cement and kiln dust applications did not differ significantly at 30-45 and 45-60 DAS,

Table 6. Effect of dust pollution on crop growth rate (CGR)

$g/m^2/day$

Treatments	Days after sowing (1987)					Days after sowing (1988-89)			
	25-40	40-55	55-70	70-85	85-100	30-45	45-60	60-75	75-90
Soil dust	16.20	17.87	23.04	7.06	5.59	13.58	27.75	10.71	4.75
Cement dust	16.06	17.38	22.26	7.66	4.75	13.50	27.86	9.95	4.32
Kiln dust	-	-	-	-	-	13.43	26.77	9.78	5.22
'F' test	NS	NS	NS	NS	NS	NS	NS	Sig.	Sig.
SE(m) ±	0.19	0.27	0.30	0.37	0.35	0.22	0.34	0.33	0.19
C.D.(5%)	-	-	-	-	-	-	-	0.94	0.55
0 g/m^2	17.47	18.66	23.64	8.36	5.81	15.08	30.68	10.49	4.78
1 "	16.53	18.41	22.91	7.85	5.44	14.48	28.68	10.32	4.73
3 "	15.83	17.36	22.28	6.87	5.11	12.37	26.15	9.64	4.95
5 "	14.71	16.07	21.77	6.36	4.31	12.09	24.32	10.13	4.60
'F' test	Sig.	Sig.	Sig.	NS	NS	Sig.	Sig.	NS	NS
SE(m) ±	0.26	0.38	0.43	0.52	0.50	0.29	0.46	0.36	0.26
C.D.(5%)	0.80	1.17	1.31	-	-	0.83	1.32	-	-
C.V.%	4.02	5.34	4.66	17.27	13.69	6.39	5.01	10.69	16.18
Test for Interaction									
'F' test	NS	NS	NS	NS	NS	NS	NS	NS	NS
SE(m) ±	0.37	0.54	0.61	0.73	0.71	0.43	0.69	0.54	0.39
CD(5%)	-	-	-	-	-	-	-	-	-

however, significant differences were noted at 60-75 DAS and 75-90 DAS. During 60-75 DAS, kiln dust had significantly lower CGR than control. Mean CGR of cement and kiln dust and soil and cement dust were at par. At 75-90 DAS cement dust recorded significantly lower CGR than kiln dust. The CGR under kiln and soil dust applications as well as under soil and cement dust applications were at par.

The effects of levels of dust applications were significant at 25-40, 40-55 and 55-70 DAS during 1987-88 and at 30-45 and 45-60 during the year 1988-89. At rest of the growth stages, effects of levels of applications were not significant. During the year 1988-89, the CGR showed gradual increase with age upto 55-70 DAS and upto 45-60 DAS during 1988-89, respectively. CGR gradually declined during latter stages of growth. At 25-40 DAS stage (1987-88), CGR under 1g, 3g and 5.0 g/m^2 levels of dust applications showed significant reduction over control. CGR under 1.0g and 3.0 g/m^2 levels were at par and were significantly higher than 5.0 g/m^2 dust applications. At 40-55 DAS stage dust applications at 3.0 g and 5.0 g/m^2 levels showed significantly lower CGR than control. The dus application at the rate of 5.0 g/m^2 showed significantly lowest CGR value. CGR at control and 1.0 g/m^2 dust applications as well as 1.0 g and 3.0 g/m^2 dust application were at par. At 55-70 DAS stage, CGR under control and

1.0 g/m^2 dust application treatments were at par. Dust applications at 3.0 and 5.0 g/m^2 levels had significantly lower CGR values than control. CGR under 1.0 g, 3.0 g and 5.0 g/m^2 levels were at par.

During the year 1988-89, at 30-45, 60-75 and 75-90 DAS stages, effects of graded levels of dust applications on CGR were not significant. The CGR values recorded significant differences at 45-60 DAS stage. At this stage CGR values of control plants (30.68 g/m^2) was significantly higher than all levels of applications (1.0 g, 3.0 g and 5.0 g/m^2). The mean CGR values of 1.0 g, 3.0 g and 5.0 g/m^2 levels also differed significantly amongst each other. The minimum CGR was observed in 5 g/m^2 (24.32 g/m^2) dust application treatment and maximum in control (30.68 g/m^2). Rest of the treatments had intermediate CGR.

4.7 Effect of Dusts Pollution on Relative Growth Rate (RGR)

Data presented in Table 7 revealed that relative growth rate gradually declined from 25-40 to 85-100 DAS and 30-45 to 75-90 DAS during year 1987-88 and 1988-89, respectively. Effects of dusts on relative growth rate showed significant difference at 25-40 DAS(1987-88) and 30-45, 45-60 and 75-90 DAS during 1988-89. At rest of the stages, soil dust and cement applications showed non-significant differences. During the year 1987-88 cement dust, showed significantly higher RGR (0.0997 g/m^2/day)

Table 7. Effect of dust pollution on relative growth rate (RGR) (g/m^2/day).

Treatments	Days after sowing (1987-88)					Days after sowing (1988-89)			
	25-40	40-55	55-70	70-85	85-100	30-45	45-60	60-75	75-90
Soil dust	0.0953	0.0407	0.0309	0.0072	0.0052	0.0423	0.0455	0.0115	0.0045
Cement dust	0.0997	0.0406	0.0307	0.0079	0.0045	0.0449	0.0461	0.0111	0.0043
Kiln dust	-	-	-	-	-	0.0428	0.0441	0.0109	0.0052
'F' test	Sig.	NS	NS	NS	NS	Sig.	Sig.	NS	Sig.
SE(m) ±	0.0010	0.0004	0.0004	0.0003	0.0001	0.0003	0.0003	0.0003	0.0002
C.D.(5%)	0.0030	-	-	-	-	0.0009	0.0009	-	0.0005
0 g/m^2	0.0933	0.0394	0.0299	0.0080	0.0051	0.0420	0.0451	0.0104	0.0041
1 "	0.0920	0.0403	0.0298	0.0078	0.0049	0.0450	0.0446	0.0107	0.0044
3 "	0.0995	0.0411	0.0309	0.0072	0.0049	0.420	0.0457	0.0112	0.0051
5 "	0.1063	0.0417	0.0326	0.0071	0.0044	0.0447	0.0456	0.0124	0.0050
'F' test	Sig.	NS	Sig.	NS	NS	Sig.	NS	Sig.	Sig.
SE(m) ±	0.0014	0.0007	0.0006	0.0004	0.0003	0.0005	0.0004	0.0004	0.0002
C.D.(5%)	0.0044	-	0.0019	-	-	0.0002	-	0.0001	0.0006
C.V.%	3.71	4.40	5.23	14.54	11.77	3.79	3.35	14.16	13.58
Test for Interaction									
'F' test	NS	NS	NS	NS	NS	NS	NS	NS	NS
SE(m) ±	0.0021	0.0010	0.0009	0.0006	0.0005	0.0008	0.0007	0.0008	0.0003
C.D.(5%)	-	-	-	-	-	-	-	-	-

than soil dust application at 25-40 DAS. During 1988-89, at 30-45 DAS cement dust application (0.0449 g/m^2/day) showed significantly higher RGR than soil and kiln dust applications. The RGR values of soil and kiln dust applications were at par. At 45-60 DAS stage, RGR values of cement and soil dusts applications were at par. The RGR values of cement and soil dust applications were significantly higher than kiln dust application. At 75-90 DAS stage, maximum RGR was recorded by kiln dust application and was significantly higher than soil and cement dusts applications. Minimum RGR was observed in cement dust application which was significantly lower than soil dust application.

The effects of graded levels of dusts applications on RGR were significant at 25-40 and 55-70 DAS during 1987-88, and at 30-45, 60-75 and 75-90 DAS stages during 1988-89,respectively. At rest of the stages, effects of levels of dusts applications were not significant. At 25-40 DAS stage (1987-88), maximum RGR was observed at 5.0 g/m^2 dust applications which was significantly higher than rest of the levels (control, 1.0 g and 3.0 g/m^2). Minimum RGR was observed in 1.0 g/m^2 dust application. The RGR values amongst the levels of applications varied significantly. Similar trend was observed at 55-70 DAS stage. During the year 1988-89, at 30-45 DAS stage maximum RGR was observed in 1.0 g/m^2 dust application and minimum in 3.0 g/m^2 dust application (0.0420 $g/m^2/day$) treatment. The RGR value amongst the levels differed significantly. At 60-75 DAS stage, minimum RGR was observed in control (0.0104 $g/m^2/day$) and maximum in 5.0 g/m^2 dust applications. The RGR gradually increased with increased levels of dust applications. Mean differences amongst the levels were significant.

The interaction effects were not significant.

4.8 Effect of Dusts Pollution on Net Assimilation Rate (NAR)

Net assimilation rate is a measure of apparent photosynthesis. The growth and yield of plants are dependent on photosynthate assimilated. It also measures the capacity of the leaves to produce and assimilate dry matter. The net assimilation rates were calculated periodically and are presented in Table 8.

The inspection of Table 8 indicated maximum NAR during early phase of growth (1.960 $g/dm^2/day$ in soil dust at 25-40 DAS) which gradually declined with advancement in age attaining minimum values at 85-100 DAS(0.121 $g/dm^2/day$). Similar trend was followed by cement dust under all levels of dusts application, during the year 1987-88. During 1988-89, maximum NAR values were recorded at 45-60 DAS stage. NAR values were lower during earlier (30-45 DAS) and latter phases. The effects of dusts (soil and cement) on NAR were significant at 25-40, 70-85

Table 8. Effect of dust pollution on net assimilation rate (NAR) mg/plant/day.

Treatments	Days after sowing (1987-88)					Days after sowing (1988-89)			
	25-40	40-55	55-70	70-85	85-100	30-45	45-60	60-75	75-90
Soil dust	1.960	1.130	0.913	0.186	0.121	1.080	1.270	0.325	0.093
Cement dust	2.240	1.170	0.896	0.202	0.097	1.130	1.330	0.286	0.099
Kiln dust	-	-	-	-	-	1.100	1.220	0.283	0.010
'F' test	Sig.	NS	NS	Sig.	Sig.	NS	Sig.	Sig.	NS
SE(m)±	0.079	0.038	0.024	0.004	0.005	0.053	0.028	0.011	0.003
C.D.(5%)	0.241	-	-	0.011	0.015	-	0.080	0.032	-
0 g/m^2	2.310	1.270	0.939	0.210	0.120	1.260	1.360	0.328	0.107
1 "	2.050	1.130	0.904	0.204	0.114	1.170	1.320	0.300	0.100
3 "	2.040	1.110	0.890	0.186	0.108	1.020	1.230	0.788	0.095
5 "	1.990	1.080	0.884	0.178	0.093	0.950	1.190	0.276	0.087
'F' test	NS	NS	NS	Sig.	NS	Sig.	Sig.	Sig.	Sig.
SE(m)±	0.112	0.053	0.034	0.005	0.007	0.061	0.032	0.013	0.004
C.D.(5%)	-	-	-	0.015	-	0.177	0.092	0.037	0.011
C.V.%	13.054	11.300	9.086	6.260	16.093	19.284	8.651	15.045	13.603
Test for Interaction									
'F' test	NS	NS	NS	NS	NS	NS	NS	NS	NS
SE(m)±	0.159	0.053	0.047	0.007	0.010	0.107	0.055	0.022	0.007
C.D.(5%)	-	-	-	-	-	-	-	-	-

and 85-100 DAS during 1987-88 and at 45-60, 60-75 DAS stage during 1988-89, respectively. At remaining stages of growth, NAR values were not significant. Amongst dusts, cement dust recorded significantly higher NAR at 25-40, 70-85 DAS (1987-88) and at 45-60 DAS stage (1988-89). At 85-100 DAS(1987-88) and 60-75 (1988-89) DAS stage, soil dust recorded significantly higher NAR values over rest of the dusts.

The effects of graded levels of dusts applications were significant only at 70-85 DAS stage during 1987-88. The effects were significant at all the stages during 1988-89. During the year 1987-88 (70-85 DAS stage), maximum NAR was recorded in control (0.210 $g/dm^2/day$). NAR values gradually and significantly decreased with every increase in level of dust application. Minimum NAR (0.178 $g/dm^2/day$) was noted in 5.0 g/m^2 dust applications. Similar trend was observed during the year 1988-89.

Interaction effects were not significant during both the seasons.

4.9 Effect of Dust Pollution on Chlorophyll Content(60 DAS)

Data presented in Table 9 revealed that chlorophyll content of wheat leaves was significantly decreased by cement dust application over soil dust during 1987-88. During the year 1988-89, the kiln dust exhibited significantly lower chlorophyll content than cement and soil dusts. The mean chlorophyll contents of cement and soil dusts were at par.

Table 9. Effect of dust pollution on total chlorophyll content (mg/g fresh weight)

Concentration / Treatments	1987-88					1988-89				
	0	1	3	5	Mean	0	1	3	5	Mean
Soil dust	3.13	2.83	2.54	2.29	2.70	3.12	2.77	2.49	2.39	2.69
Cement dust	2.98	2.60	2.37	2.07	2.51	3.12	2.72	2.53	2.33	2.68
Kiln dust	-	-	-	-	-	3.07	2.54	2.42	2.30	2.58
Mean	3.06	2.72	2.46	2.18		3.10	2.68	2.48	2.34	

	1987-88 T	1987-88 C	1987-88 TxC	1988-89 T	1988-89 C	1988-89 TxC
'F' test	Sig.	Sig.	NS	Sig.	Sig.	Sig.
SE(m)±	0.05	0.08	0.11	0.02	0.03	0.05
C.D.(5%)	0.16	0.23	-	0.07	0.08	0.14
C.V.%	7.16			3.69		

The effects of levels of dusts applications on chlorophyll content were significant during both the seasons. The chlorophyll contents were significantly reduced at all levels of dust applications over control. Maximum chlorophyll content (3.06 mg and 3.10 mg) was observed in control (no dust application). Chlorophyll content gradually decreased as the doses of dust applications were increased. Minimum chlorophyll content (2.51 and 2.58) was observed at 5.0 g/m^2 dust application.

The interaction effects were non-significant in the first season. In the second season, interaction effects were significant. Soil, cement and kiln dusts applications recorded significant reduction in chlorophyll contents over control. In soil and cement dust application treatments, significant reduction in chlorophyll content was observed with every increased level of dust application. While in kiln dust application, 1 g/m^2 dust application had significantly lower chlorophyll content than control. 3 g/m^2 and 5.0 g/m^2 kiln dusts also showed significantly lower chlorophyll contents than 1.0 g/m^2 dust. Chlorophyll contents at 3.0 and 5.0 g/m^2 kiln dust applications were at par. At 1.0 g/m^2 dust application level, kiln dust had significantly lower chlorophyll than soil and cement dust. Chlorophyll contents of cement and soil dusts were at par. At 3.0 and 5.0 g/m^2 dust application levels, chlorophyll contents amongst dusts were at par.

4.10 Effect of Dust Pollution on Rate of Transpiration

Data presented in Table 10 revealed that rate of transpiration of wheat crop was significantly reduced by dust applications during 1988-89. Amongst dusts, cement and kiln dust had significantly lower rate of transpiratio than soil dust. During the year 1987-88, the effects of different types of dusts on rate of transpiration were non-significant.

The effects of graded concentrations of dust applications on rate of transpiration were significant during both the seasons. The rate of transpiration was significantly reduced at all levels of dusts applications over control. Maximum rate of transpiration (4.52 and 4.60 $g/dm^2/h$) was observed in control (No dust applications). Rate of transpiration decreased as the dos of dust applications were increased. Minimum rate of transpiration was observed at 5.0 g/m^2 dust application.

The interaction effects were non-significant during 1987-88, however, were significant during 1988-89. These results indicated that irrespective of source of dusts, higher depositions on plants reduced rate of transpiration.

Table 10. Effect of dust pollution on rate of transpiration. ($g/dm^2/hour$)

Concentration / Treatments	(1987-88)					(1988-89)				
	0	1	3	5	Mean	0	1	3	5	Mean
Soil dust	4.53	3.32	2.98	2.80	3.41	4.58	3.99	3.63	3.51	3.93
Cement dust	4.50	3.21	2.81	2.61	3.28	4.64	3.74	3.20	2.98	3.64
Kiln dust	-	-	-	-	-	4.59	3.79	3.23	3.03	3.66
Mean	4.52	3.27	2.90	2.71		4.60	3.84	3.35	3.17	
	T	C	TxC			T	C	TxC		
'F' test	NS	Sig.	NS			Sig.	Sig.	Sig.		
SE(m)±	0.04	0.06	0.09			0.04	0.05	0.07		
C.D.(5%)	-	0.19	-			0.10	0.14	0.20		
C.V.%	4.56					3.78				

4.11 Effect of Dust Pollution on Biomass of Wheat

Data presented in Table 11 showed non-significant effects of types of dusts on biomass production in 1987-88. However, during 1988-89, types of dusts recorded significant effects. Soil dust application recorded significantly higher biomass of wheat followed by cement and kiln dust in order. Minimum biomass (606.94 g/m^2) was observed in kiln dust application.

The doses of dust applications showed significant differences in respect of biomass production during both the seasons. Maximum biomass (595.16 and 683.25 g/m^2) was observed in control (no dust application). Biomass/m^2 gradually decreased as the rates of dust applications were increased. Minimum biomass (488.33 and 537.75 g/m^2) was observed at 5.0 g dust applications. Rest of the treatments recorded intermediate biomass between control and 5.0 g/m^2 dust applications.

Interaction effects were significant during both the seasons. Soil dust application recorded significant reduction in biomass with every increased level of dust application. While in case of cement dust, significant reduction in biomass was observed at 3 g and 5 g dust/m^2 applications. Kiln dust application also showed significant reduction at 5.0 g/m^2 dust application. The biomass

Table 11. Effect of dust pollution on biomass (g/m^2)

Concentration / Treatments	(1987-88) 0	1	3	5	Mean	(1988-89) 0	1	3	5	Mean
Soil dust	593.33	570.00	530.00	510.00	550.83	687.50	662.24	645.00	572.50	641.81
Cement dust	597.00	583.33	536.66	466.66	545.91	685.50	632.00	596.25	525.00	609.68
Kiln dust	-	-	-	-	-	676.75	622.00	613.25	515.75	606.94
Mean	595.16	576.66	533.33	488.33		683.25	638.74	618.16	537.75	
		T	C	TxC			T	C	TxC	
'F' test		NS	Sig.	Sig.			Sig.	Sig.	Sig.	
SE(m)±		3.55	5.02	7.10			1.84	2.13	3.68	
C.D.(5%)		-	15.22	21.53			5.30	6.12	10.60	
C.V.%		2.24					1.20			

productions at 1.0 g and 3.0 g/m^2 kiln dust applications were at par.

During the year 1987-88, the mean biomass of wheat was not affected by types of dusts (soil and cement) at 0, 1.0 and 3.0 g concentrations. However, at 5.0 g/m^2 dose, cement dust showed significantly lower biomass production than soil dust.

In 1988-89, soil dust at 1.0, k3.0 and 5.0 g/m^2 dust applications recorded significantly higher biomass than cement and kiln dusts. The cement and kiln dust differed significantly at 3.0 g/m^2 dose while mean biomass at 1.0 g and 5.0 g/m^2 doses were at par.

4.12 Effect of Dust Pollution on Number of Ears/m^2

Data presented in Table 12 revealed that number of ears/m^2 of wheat crop were significantly reduced by dust applications in both the seasons. Amongst dusts, cement dust had significantly lower number of ears/m^2 than soil dust in the first season. During the year, 1988-89, soil, cement and kiln dusts differed significantly. Maximum number of ears/m^2 (302.23) were recorded in soil dust application while minimum (286.90) ears/m^2 were recorded in kiln dust application. Cement dust application had intermediate ears/m^2.

Table 12. Effect of dust pollution on number of ears/m^2

Concentration / Treatments	(1987-88) 0	1	3	5	Mean	(1988-89) 0	1	3	5	Mean
Soil dust	215.66	203.33	194.33	178.33	197.91	320.25	308.41	295.00	285.25	302.23
Cement dust	216.00	193.33	187.00	166.00	188.08	324.25	302.50	267.00	258.25	292.50
Kiln dust	-	-	-	-	-	322.36	299.75	268.00	257.50	286.90
Mean	215.83	198.33	190.66	172.16		322.29	303.55	276.67	261.00	
		T	C	TxC			T	C	TxC	
'F' test		Sig.	Sig.	NS			Sig.	Sig.	Sig.	
SE(m)±		1.57	2.22	3.14			1.67	1.93	3.34	
C.D.(5%)		4.76	6.73	-			4.81	5.56	9.63	
C.V.%		2.82					2.30			

The effects of graded levels of dust applications on number of ears/m^2 were significant during both the seasons. Number of ears/m^2 were significantly decreased at all levels of dust applications over control. Maximum number of ears/m^2 (215.83 and 322.29) were observed in control (no dust application). Number of ears/m^2 were significantly decreased as the doses of dust applications were increased. Minimum number of ears/m^2 (172.16 and 261.00) were observed at 5.0 g/m^2 dust application. Rest of applications showed intermediate ear number.

The interaction effects were non-significant in the first season. In the second season, interaction effects were significant.

At 1.0 g/m^2 dust application level, mean number of ears/m^2 in all dusts were at par. However, at 3.0 and 5.0 g/m^2 treatments, cement and kiln dust had significantly lower ear number than soil dust application. Mean number of ears/m^2 were at par at 3.0 and 5.0 g/m^2 cement and kiln dust applications.

Reduction in ear number/m^2 was observed with increased rates of dust applications by soil, cement and kiln dusts. All dust applications significantly and gradually decreased ear number with every increase in the level of dust application. Maximum ear number was observed in control and minimum in 5.0 g/m^2 dust application.

4.13 Effect of Dust Pollution on Number of Spikelets/Earhead

Data presented in Table 13 revealed that number of spikelets/earhead of wheat crop were significantly reduced by dust applications in both the seasons. Amongst dusts, cement dust showed significantly lower number of spikelets/earhead than soil dust in both the seasons.

In 1988-89, Kiln dust had significantly lower spikelets/ear than soil dust at dust levels of 3 & 5 g/m².

The effects of graded levels of dust applications on number of spikelets/earhead were significant during both the seasons. Number of spikelets/earhead were significantly decreased at all levels of dusts applications over control. Maximum number of spikelets/earhead (18.70 and 15.84) were observed in control (no dust application). Number of spikelet/earhead significantly and gradually decreased as the levels of dust applications were increased. Minimum number of spikelet/earhead were observed at 5.0 g/m^2 dust application (17.13 and 13.61).

The interaction effects were not significant in the first season. In the second season, interaction effects were significant. At all concentrations (1.0, 3.0 and 5.0 g/m^2), soil dust applications recorded greater number of spikelets/earhead than cement and kiln dust applications. At 1.0 g/m^2 level, cement dust application had significantly lower spikelets than kiln dust. Mean spikelet number/ear i

Table 13. Effect of dust pollution on number of spikelet/earhead

Concentration g/m² / Treatments	(1987-88) 0	1	3	5	Mean	(1988-89) 0	1	3	5	Mean
Soil dust	18.62	18.26	17.73	17.33	17.98	15.82	15.07	14.41	13.98	14.82
Cement dust	18.78	17.81	17.33	16.93	17.71	15.82	14.43	14.24	13.44	14.48
Kiln dust	-	-	-	-	-	15.87	14.82	14.22	13.42	14.58
Mean	18.70	18.04	17.53	17.13		15.84	14.77	14.29	13.61	

	T	C	TxC	T	C	TxC
'F' test	Sig.	Sig.	NS	Sig.	Sig.	Sig.
SE(m)±	0.09	0,12	0.17	0.02	0.02	0.04
C.D.(5%)	0.26	0.37	-	0.06	0.07	0.12
C.V. %	1.68			0.59		

3.0 g and 5.0 g/m^2 cement and kiln dust applications were at par.

Soil, cement and kiln dusts showed significant trend of reduction in spikelet number/earhead with every increased level of dust application. Control (no dust applications) recorded maximum spikelets/ear. While minimum number of spikelets/ear were recorded at 5.0 g/m^2 dust. Rest of the levels had intermediate spikelet number.

4.14 Effect of Dust Pollution on Number of Grains/Earhead

Inspection of data presented in Table 14 revealed non-significant effects of types of dusts (cement, soil and kiln) on number of grains/earhead in both the seasons of study. However, numerical comparison of means showed maximum grains/ear head in soil dust application followed by cement in 1987-88 and soil dust followed by kiln dust and cement dust in order in 1988-89.

The effects of levels of dust applications on number of grains/earhead were significant during both the seasons. Number of grains/earhead were significantly lower at all levels of dusts applications over control. Maximum number of grains/earhead (72.70 and 50.41) were observed in control(no dust application). Number of grains/earhead gradually decreased as the doses of dust applications were increased. Minimum number of

Table 14. Effect of dust pollution on number of grains/earhead

Concentration / Treatments	(1987-88) 0	1	3	5	Mean	(1988-89) 0	1	3	5	Mean
Soil dust	72.73	65.60	61.70	58.80	64.70	50.44	48.47	45.98	44.37	47.32
Cement dust	72.66	67.33	61.86	54.60	64.11	50.44	48.20	44.13	41.50	46.06
Kiln dust	-	-	-	-	-	50.36	48.42	44.18	41.45	46.10
Mean	72.70	66.46	61.78	56.70		50.41	47.71	44.76	42.44	
		T	C	TxC			T	C	TxC	
'F' test		NS	Sig.	NS			NS	Sig.	NS	
SE(m)±		0.84	1.19	1.68			0.44	0.51	0.88	
C.D.(5%)		-	3.61	-			-	1.47	-	
C.V.%		4.52					3.80			

grains/earhead were observed at 5.0 g/m^2 dust application (56.70 and 42.44).

The interaction effects were non-significant in both seasons.

4.15 Effect of Dust Pollution on Thousand Grain Weight

Data presented in Table 15 indicated significant reduction in test weight (1000 grain weight) of wheat by cement dust application over soil dust application during both the seasons. Kiln dust application (1988-89) recorded significantly lower test weight than soil dust application. Test weights of cement dust and kiln dust applications were at par.

The effects of graded levels of dust applications on test weights were significant during both the seasons. The test weights were significantly reduced at all levels of dusts applications over control. Maximum test weight (36.50 g and 35.93 g) was observed in control (no dust application). Test weight gradually decreased as the doses of dust applications were increased. Minimum test weight was observed at 5.0 g/m^2 dust application(34.03 and 33.12 g).

The interaction effects were non-significant in the first season. In the second season interaction effects were significant. Test weight of control and 1.0 g/m^2 soil dust

Table 15. Effect of dust pollution on thousand grain weight (g)

Concentrations / Treatments	(1987-88) 0	1	3	5	Mean	(1988-89) 0	1	3	5	Mean
Soil dust	36.64	36.20	36.00	34.21	35.76	35.99	35.82	34.07	33.88	34.94
Cement dust	36.35	35.35	35.01	33.85	35.14	35.98	34.33	32.65	32.25	33.80
Kiln dust	-	-	-	-	-	35.82	33.80	33.55	33.25	34.10
Mean	36.50	35.78	35.50	34.03		35.93	34.65	33.42	33.12	
		T	C	TxC		T	C	TxC		
'F' test		Sig.	Sig.	NS		Sig.	Sig.	Sig.		
SE(m)±		0.12	0.17	0.24		0.15	0.17	0.30		
C.D.(5%)		0.37	0.52	-		0.43	0.49	0.86		
C.V. %		1.18								

applications were at par. These treatments recorded significantly higher test weight over 3.0 and 5.0 g/m^2 soil dust applications. Test weights of 3.0 g and 5.0 g/m^2 soil dusts were at par. Similar trend was observed in cement dust applications. The kiln dust application recorded significantly higher test weight in control over all doses used (1.0, 3.0 and 5.0 g). The test weight of 1.0 g, 3.0 g and 5.0 g/m^2 dust applications were at par.

At 1.0 g and 5.0 g levels of dust applications, cement and kiln dust applications recorded significantly lower test weights than soil dust application. At these levels, test weights of kiln and cement dusts were at par. At 3.0 g/m^2 level, test weight of soil and kiln dusts were at par and significantly higher than cement dust application.

4.16 Effect of Dust Pollution on Yield of Wheat

Data (Table 16) showed significant effects of main (dusts) and sub-treatments (concentrations) on grain yield of wheat during both the seasons. Soil dust application recorded significantly higher grain yield (205.66 and 286.04 g/m^2) than cement (197.41 and 267.25 g) and kiln dust (271.55 g) applications. Grain yield of kiln dust and cement dust applications (1988-89) were at par.

Table 16. Effect of dust pollution on yield of wheat g/m^2

Concentrations / Treatments	(1987-88) 0	1	3	5	Mean	(1988-89) 0	1	3	5	Mean
Soil dust	232.00	209.00	200.00	181.66	205.66	302.16	291.25	287.50	263.25	286.84
Cement dust	228.00	205.00	181.66	175.00	197.41	303.75	272.00	257.50	235.75	267.25
Kiln dust	-	-	-	-	-	299.69	281.00	268.75	236.75	271.55
Mean	230.00	207.00	190.83	178.33		301.87	281.42	271.25	245.25	
	T	C	TxC			T	C	TxC		
'F' test	Sig.	Sig.	NS			Sig.	Sig.	Sig.		
SE(m)±	1.70	2.40	3.39			1.66	1.92	3.33		
C.D.(5%)	5.14	7.27	-			4.79	5.53	9.58		
C.V.%	2.91					2.41				

The effect of levels of dust applications on grain yield were significant during both the seasons. The grain yield was significantly reduced at all levels of dust applications over control. Maximum yield (230.00 g and 301.87 g) was observed in control (no dust application). Grain yield gradually decreased as the levels of dust applications were increased. Minimum grain yield was observed at 5.0 g dust application (178.33 and 245.25 g). Rest of the doses recorded intermediate yields.

The interaction effects were non-significant in the first season. However, in second season,interaction effects were significant. All concentrations of soil, cement and kiln dusts (1.0, 3.0 and 5.0 g) recorded significantly lower grain yields than control. Grain yield at 1.0 and 3.0 g/m^2 soil dust applications were at par and were significantly higher than 5.0 g soil dust application treatment. However, in case cement and kiln dust applications, grain yields were significantly and gradually reduced at all the concentrations studied. Maximum yield was observed in control and minimum in 5.0 g/m^2 dust application treatment.

At 1.00 and 5.0 g/m^2 concentrations, grain yield of cement and kiln dust applications were at par and significantly lower than soil dust at similar rates of application. However, at 3.0 g/m^2 dust application treatment, grain yield was significantly affected by types of dusts. Maximum grain yield at this level was recorded by soil dust followed by kiln dust and cement dust in order.

4.17 Effect of Dust Pollution on Harvest Index (HI)

Harvest index exhibits the pattern of dry matter partitioning in plants. It also exhibits direct relation with economic yield. The harvest index estimates were made from the data and are presented in Table 17.

Scrutiny of data presented in Table 17 indicated non-significant effects of types of dusts on harvest index during 1987-88. However, significant effects were noted during 1988-89. During the year 1988-89 harvest index of soil dust and kiln dusts were at par. Cement dust application had significantly lower HI than soil and kiln dusts.

The levels of dust applications exhibited significant differences during both the seasons. During 1987-88, maximum HI was recorded in control plants. All levels of dust applications (1, 3 and 5 g/m^2) showed significantly lower HI than control. The harvest index of 1, 3 and 5 g/m^2 were at par. During 1988-89, maximum HI was observed in 5 g/m^2 dust application, which was significantly higher than rest of the treatments. The HI of control, 1 and 3 g/m^2 were at par.

Table 17. Effect of dust pollution on harvest index (%).

Concentrations / Treatments	(1987-88) 0	1	3	5	Mean	(1988-89) 0	1	3	5	Mean
Soil dust	39.11	36.66	37.75	35.61	37.28	43.95	43.98	44.57	45.98	44.62
Cement dust	38.18	35.14	33.85	37.54	36.18	44.31	43.04	43.19	44.91	43.86
Kiln dust	-	-	-	-	-	44.28	45.18	43.82	45.90	44.80
Mean	38.65	35.90	35.80	36.47		44.18	44.07	43.86	45.60	
	T	C	TxC			T	C	TxC		
'F' test	NS	Sig.	Sig.			Sig.	Sig.	NS		
SE(m)±	0.38	0.54	0.76			0.27	0.36	0.54		
C. D.(5%)	-	1.63	2.31			0.78	1.04	-		
C. V.%	3.59					2.43				

Interaction effects were significant during both the seasons. In case of soil dust during 1987-88, control and 3 g/m^2 dust application showed similar HI. While HI of 1.0 g and 5.0 g/m^2 dust application were at par. These estimates were significantly lower than control. In case of cement dust, HI of control and 5.0 g/m^2 dust application were at par and were significantly superior over 1 g and 3 g/m^2 dust application. Harvest index of 1 g and 3 g/m^2 were also at par. During 1988-89 maximum, HI estimates were observed in 5 g/m^2 dust application (cement, soil and kiln dust). 1 g, 3 g/m^2 and control had more or less similar HI.

4.18 Correlation of Dust Pollution with Yield and Growth Parameters of Wheat

In order to find out whether concentration level of dust pollution has any relationship either with yield of wheat or with growth parameters of the crop, the product movement correlation coefficients has been studied. The correlation coefficients worked out for the pollution of different dusts as well as overall dust pollution are presented in Table 18.

The Table 18 indicated, in general, the *negative* relationship of concentration level of pollution with almost all the growth parameters and also with the yield under pollution of all the types of dust, i.e. *soil, cemen* and kiln dust. However, in case of soil and cement dusts

Table 18. Correlation coefficients between dust concentration and biometrical/physiological characters and yield of wheat.

Sr. No.	Characters	Soil dust	Cement dust	Kiln dust	Overall dust
	Biometrical characters				
1.	Yield/m^2	-0.353+	-0.527**	-0.960**	-0.474**
2.	No.of earhead/m^2	-0.247	-0.407*	-0.949**	-0.374**
3.	No.of spikelets/ earhead	-0.352+	-0.403*	-0.948**	-0.404**
4.	No.of grains/ earhead	-0.356+	-0.458*	-0.907**	-0.410**
5.	Thousand grain weight	-0.777**	-0.787**	-0.331	-0.639**
6.	Max LAI	-0.404*	-0.537**	-0.521*	-0.454**
7.	Biomass/m^2	-0.622**	-0.849**	-0.940**	-0.769**
	Physiological characters				
8.	Chlorophyll content	-0.888**	-0.884**	-0.748**	-0.819**
9.	Rate of transpiration	-0.719**	-0.824**	-0.882**	-0.787**
10.	Max.RGR	0.085	0.145	-0.710**	0.083
11.	Max. NAR	-0.145	-0.192	-0.719**	-0.180

** Significant at 1 % level

* Significant at 5% level

\+ Significant at 10% level

and overall dust pollutions, the characters maximum RGR and maximum NAR were not found to be related with the dust concentration level. Similarly, number of earheads/m^2 under soil dust and thousand grain weight under kiln dust indicated relationship with dust concentration at 20% level of significance.

4.19 Influence of Dust Pollution on Yield and Growth Parameters of Wheat

Since almost every character was found to be related with dust concentration level, linear regressions of these characters on dust concentration have been fitted to assess the magnitude of the influence of pollution. These fitted regressions are given in Appendix-I and the elasticities (i.e.percentage change in dependent character for certain percentage change in pollution level) as worked out from these regressions are presented in Table 19.

The elasticities presented in Table 19 revealed detrimental effects of dust on yield, yield attributes and physiological parameters except maximum RGR under soil, cement and kiln dusts treatments. Amongst dusts, cement dust exhibited maximum detrimental effects followed by kiln dust and soil dust in order. The physiological characters, namely, chlorophyll content and rate of transpiration were the much affected characters by dusts pollution. Rate of transpiration was greatly affected

Table 19. Elasticities of biometrical and physiological characters to dust concentration under different types of dust in wheat

Sr. No.	Characters	Elasticity(%) to concentration of			
		Soil dust	Cement dust	kiln dust	Overall dust
	Biometrical characters				
1.	Yield/m^2	-7.089	-10.865	- 9.714	- 9.113
2.	No.of earheads/m^2	- 6.019	-10.458	-10.149	- 8.670
3.	No.of spikelets/ earhead	- 4.447	- 5.331	- 5.820	- 5.081
4.	No.of grains/ earhead	- 7.714	-10.412	- 8.453	- 8.937
5.	Thousand grain weight	- 2.958	- 3.986	- 1.588	- 3.045
6.	Max. LAI	- 2.422	- 3.987	- 2.609	- 3.066
7.	Biomass/m^2	- 7.261	-10.947	-10.605	- 9.420
	Physiological characters				
8.	Chlorophyll content	-12.333	-13.327	- 6.351	-11.466
9.	Rate of transpiration	-14.616	-20.431	-17.951	-17.576
10.	Max. RGR	3.214	6.429	- 5.625	3.75
11.	Max. NAR	- 4.156	- 6.373	- 8.598	- 5.952

followed by chlorophyll content indicating the disturbance in gaseous exchange and degeneration of photosynthetic apparatus. Amongst the yield contributing characters, number of ears/m^2, number of spikelets/earhead showed reductions under dusts applications.

The types of dusts exhibited varying effects on yield attributes. Cement dust recorded maximum percentage reduction in case of ear number/m^2, biomass/m^2 and maximum LAI followed by kiln dust and soil dust in order. Kiln dust exhibited maximum percentage reduction in number of spikelets/earhead and number of grains/earhead followed by cement dust and soil dust in order. Soil dust did not indicate maximum reduction in any of the selected characters.

Thousand grain weight was much affected by cement dusts application followed by soil dust and kiln dust in order. Maximum NAR was greatly decreased by kiln dust pollution followed by cement and soil dust while maximum RGR was decreased by kiln dust application only. However, maximum RGR was increased by 6.429% and 3.214% by cement and soil dust application respectively.

4.20 Analysis of the Effects of Dust Pollution and Growth xParameters on Yield of Wheat

The natural relationship of growth parameters with yield and, in turn, the inter correlations amongst the growth parameters and dust pollution level has necessitated the analysis of the effect of each character into direct and indirect effects. Hence, the method of path analysis which also identifies the characters responsible for the yield has been adopted. It was observed that in either set of only biometrical characters or only physiological characters or all the characters together, the total contributions were above 90% and were not differing much. This indicates that any of the sets of either biometrical characters or of physiological characters is sufficient to explain the variation in yield. As such path analysis have not been done for all the characters together but for the biometrical and physiological characters separately.

4.20.1 Effect of biometrical characters on yield :

The results of the path analysis on dust pollution and biometrical character with yield of wheat as dependent character are presented in Table 20.1(a) to Table 20.1(e).

4.20.1.1 Effects under dust free environment :

Data presented in Table 20.1(a) indicated significant and high degree of total association between biometrical characters and yield under dust free environment. The direct positive effect were observed for ears number/m^2 (0.5305) followed by biomass/m^2(0.2470). The number of grains/earhead though indicated the negative correlation with yield, its direct effect was positive i.e. 0.1822. Maximum LAI exhibited low direct effect

Table 20.1(a). Direct and indirect effects (path analysis) of biometrical characters under dust free environment on yield of wheat.

Chara-cter No.	Characters	Total corre-lation	Direct effect	Totality of indirect effect	Influencing character(s) & its indirect effects
2.	Thousand grain weight	-0.4290	-0.0938	-0.3352	(3)-0.1669 (5)-0.1949
3.	No.of spikelets/ earhead	-0.9869	-0.4119	-0.5750	(4) 0.1766 (5)-0.5240 (7)-0.2413
4.	No.of grains/ earhead	-0.9563	0.1822	-0.7741	(3)-0.3991 (5)-0.5165 (7)-0.2307
5.	No.of ears/m^2	0.9846	0.5305	0. 4541	(3) 0.4069 (4)-0.1774 (7) 0.2407
6.	Max. LAI	-0.7299	0.0682	-0.6617	(3)-0.3131 (4) 0.1262 (5)-0.3930 (7)-0.1749
7.	Biomass/m^2	0.9789	0.2470	0.7319	(3) 0.4025 (4)-0.1702 (5) 0.5170
12.	Dust pollution	Nil	-	-	-

(0.0682). The character, number of spikelets/earhead recorded strong negative direct effect on yield(-0.4119). The character thousand grain weight also recorded low (-0.0938) negative direct effect.

The total indirect effects indicated maximum negative indirect effects of number of grains/earhead (-0.7741) especially through number of ears/m^2, number of spikelets/earhead and biomass/m^2, followed by maximum LAI (-0.6617) through number of spikelets/earhead; number of grains/earhead; number of ears/m^2 and biomass/m^2; number of spikelets/earhead (-0.5750) through number of grains/earhead, number of ears/m^2 and biomass/m^2 and thousand grain weight (-0.3352) through number of spikelets/earhead and number of ears/m^2 in order. Biomass/m^2 exhibited maximum positive indirect effects on the yield (0.7319) through number of spikelets/earhead and number of ears/m^2 and negatively through number of grains/earhead(-0.1702). Number of ears/m^2 also exhibited greater indirect effects (0.4541) through number of spikelets/earhead and biomass/m^2. Number of ears/m^2 recorded negative indirect effects (-0.1777) through number of grains/earhead.

In general, data indicated that number of ears/m^2 and biomass/m^2 are major yield contributing characters. The rest of the characters showed greater negative indirect effects on yield through other characters. Number of spikelets/earhead strongly affected the yield directly as well as indirectly through other characters.

4.20.1.2 Effect under soil dust pollution :

Data presented in Table 20.1(b) indicated positive correlation between number ears/m^2; biomass/m^2 and the yield. The rest of the biometrical characters and dust pollution exhibited negative association with the yield. Under soil dust polluted environment ear number/m^2, number of grains/earhead and biomass/m^2 exhibited positive direct effects on yield. Number of spikelets/earhead and dust pollution exhibited greater negative effects, thousand grain weight and maximum LAI showed low direct negative effects. The total indirect effects of biometrical characters under soil dust polluted environment were similar to control. The dust pollution showed indirect effects through ear number/m^2 and number of spikelets/earhead.

4.20.1.3 Effects under cement dust pollution :

Under cement dust polluted environment (Table 20.1(c), dust pollution indicated poor direct effects on yield. However, it strongly affected the yield through thousand grain weight, ears number/m^2 and biomass/m^2. The effect of dust pollution through biomass/m^2 and ears number/m^2 were negative. Rest of the characters had similar effects to that of control.

Table 20.1(c). Direct and indirect effects (path analysis) of biometrical characters and cement dust pollution on yield of wheat.

Chara-cter No.	Characters	Total corre-lation	Direct effect	Totality of indirect effect	Influencing character(s) and its indirect effects
2.	Thousand grain weight	0.0775	-0.1486	-0.0711	(3) 0.1740 (7) 0.1569
3.	No.of Spikelets/ earhead	-0.4997	0.2321	-0.7628	(2) -0.1114 (5) -0.5322
4.	No.of grains/ earhead	-0.4671	-0.0475	-0.4196	(2) -0.1071 (3) 0.2205 (5) -0.4984
5.	No.of ears/m^2	0.9695	0.8537	0.1158	(3) -0.1447 (7) 0.2623
6.	Max. LAI	-0.1523	0.0251	-0.1272	(3) 0.1648 (5) -0.2326
7.	Biomass/m^2	0.8623	0.3409	0.5218	(5) 0.6694
12.	Dust pollution	-0.5267	0.0788	-0.4479	(2) 0.1169 (5) -0.3477 (7) -0.2894

4.20.1.4 Effect under kiln dust pollution :

Kiln dust pollution (Table 20.1(d) exhibited strong direct effect on yield (-0.6201),. Kiln dust pollution recorded low negative indirect effects. It affected yield through number of spikelets/earhead (-0.2408), biomass/m^2 (-0.2691), number of grains/earhead (-0.1048) and number of ears/m^2 (0.278). Kiln dust affected yield strongly through number of ears/m^2, number of spikelets/earhead and biomass/m^2 and showed negative effects.

4.20.1.5 Effect under general pollution :

Table 20.1(e) exhibited significant negative correlation between yield and dust pollution i.e.-0.4735. The dust pollution recorded low direct effects (0.0330) on the yield. However, total indirect effects of dusts pollution through ear number/m^2 and biomass/m^2 were greater and negative.

In general, biometrical characters under dust free and polluted environment exhibited more or less similar effects on yield. Overall dust pollution and cement dust pollution affected yield through other characters while soil dust pollution and kiln dust pollution affected the yield directly.

Table 20.1(d). Direct and indirect effects (path analysis) of biometrical characters and kiln dust pollution on yield of wheat.

Character No.	Characters	Total Correlation	Direct effect	Totality of indirect effect	Influencing character(s) and its indirect effects
2.	Thousand grain weight	-0.2647	0.0844	-0.3491	(12)-0.2339
3.	No.of Spikelets/earhead	0.9210	0.2540	0.6670	(5) -0.4726 (7) 0.2628 (12) 0.7773
4.	No.of grains/ear-head	0.9041	0.1156	0.7885	(3) 0.2165 (5) -0.4261 (7) 0.2556 (12) 0.7436
5.	No.of ears/m^2	0.8790	-0.4954	1.3744	(3) 0.2423 (7) 0.2460 (12) 0.7786
6.	Max.LAI	0.5373	0.0389	0.4984	(3) 0.1188 (5) -0.2439 (7) 0.1493 (12) 0.4270
7.	Biomass/m^2	0.9589	0.2862	0.6727	(3) 0.2333 (4) 0.1032 (5) -0.4258 (12) 0.7711
8.	Dust pollution	-0.9604	-0.6201	-0.3403	(3) -0.2408 (4) -0.1048 (5) 0.2703 (7) -0.2693

Table 20.1(e). Direct and indirect effects (path analysis) of biometrical characters and overall dust pollution on yield of wheat

Character No.	Characters	Total correlation	Direct effect	Totality of indirect effect	Influencing character(s) & its indirect effects
2.	Thousand grain weight	-0.0110	0.0104	-0.0205	-
3.	Number of spikelets/earhead	-0.5405	-0.1333	-0.4104	(5) -0.4071
4.	Number of grains/earhead	-0.5252	0.0816	-0.6092	(3) -0.1263 (5) -0.4051
5.	No.of ears/m^2	0.9684	0.6392	0.3184	(7) 0.3051
6.	Max. LAI	-0.2599	-0.0093	-0.2678	(5) -0.2243
7.	Biomass/m^2	0.8755	0.3790	0.5049	(5) 0.5146
12.	Dust pollution	-0.4735	0.0330	-0.5064	(5) -0.2392 (7) -0.2915

4.20.2 Effects of physiological characters on yield :

The results of path analysis on dust pollution and physiological characters with yield as dependent character are presented in Table 4.20(a) to Table 4.20 (e).

4.20.2.1 Effects under dust free environment :

Data presented in Table 20.2(a) recorded strong negative correlation between maximum RGR and maximum NAR. Chlorophyll content exhibited poor negative association.

Rate of transpiration exhibited poor positive correlation with the yield. Maximum RGR exhibited maximum direct effect on yield. The effect of RGR on yield was however, negative. It recorded low total indirect effects. Maximum NAR recorded maximum indirect effects. The indirect effects of maximum NAR were also negative. The maximum NAR influenced the yield through maximum RGR. Chlorophyll content and rate of transpiration exhibited low indirect effects. Chlorophyll content affected yield through maximum RGR (-0.1353).

Table 20.2(a) Direct and indirect effects (path analysis) of physiological characters under dust free environment on yield of wheat

Character No.	Characters	Total correlation	Direct effect	Totality of indirect effect	Influencing character(s) & its indirect effects
8.	Chlorophyll content	-0.1168	0.0385	-0.0783	(10)-0.1353
9.	Rate of transpiration	0.1404	0.0464	0.0940	-
10.	Max. RGR	-0.9879	-0.9409	0.0470	-
11.	Max. NAR	-0.8982	-0.0539	-0.9521	(10)-0.8420

4.20.2.2 Effects under soil dust pollution :

Influence of soil dust pollution on the yield (Table 20.2(b) indicated negative direct effect of dust pollution on yield (-0.2161). Dust pollution affected wheat yield through rate of transpiration. The yield under soil dust pollution was directly affected by maximum RGR and rate of transpiration. Maximum NAR and chlorophyll content showed low direct effects on yield. Chlorophyll content, rate of transpiration and maximum NAR had greater indirect effects. Chlorophyll content affected yield through rate of transpiration and dust concentration. Rate of transpiration affected yield through maximum RGR and dust pollution, while maximum NAR influenced yield through maximum RGR. The effect of soil dust pollution were through chlorophyll content and rate of transpiration.

Table 20.2(b). Direct and indirect effects (path analysis) of physiological characters and soil dust pollution on yield of wheat.

Character No.		Total correlation	Direct effect	Totality of indirect effect	Influencing character(s) & its indirect effects
8.	Chlorophyll content	0.3240	-0.0733	0.3973	(9) 0.1318 (12) 0.1919
9.	Rate of transpiration	0.6475	0.1809	0.4666	(10) 0.3663 (12) 0.1552
10.	Max. RGR	-0.9417	-0.8470	-0.0947	-
11.	Max. NAR	-0.7486	-0.0046	-0.744	(10)-0.7241
12.	Dust pollution	-0.3526	-0.2161	-0.1365	(9) -0.1300

4.20.2.3 Effects under cement dust pollution :

The effects of physiological characters on the yield under cement dust polluted environment (Table 20.2 c) were similar to that of soil dust polluted environment. Cement dust pollution affected the yield greatly through chlorophyll content and rate of transpiration. Under cement dust polluted environment RGR directly as well as indirectly affected wheat yield.

Table 20.2(c). Direct and indirect effects (path analysis) of physiological characters and cement dust pollution on yield of wheat.

Character No.	Characters	Total correlation	Direct effect	Totality of indirect effect	Influencing character(s) and its indirect effects
8.	Chlorophyll content	0.7106	0.2103	0.5003	(9) 0.1894 (10) 0.1811 (12) 0.1203
9.	Rate of transpiration	0.6785	0.2224	0.4561	(8) 0.1791 (10) 0.1576 (12) 0.1121
10.	Max. RGR	-0.8751	-0.4826	-0.3925	(11)-0.2212
11.	Max. NAR	-0.6636	-0.2524	-0.4112	(10)-0.4230
12.	Dust pollution	-0.5267	-0.1361	-0.3906	(8) -0.1858 (9) -0.1832

4.20.2.4 Effects under kiln dust pollution :

Kiln dust pollution (Table 20.2(d) exhibited strong direct effect (-0.8201) on yield. Other physiological parameters recorded low negative direct effects. The physiological parameters however, strongly affected yield through dust pollution (indirect effects). Major indirect effects of kiln dust pollution was through maximum RGR.

Table 20.2(d). Direct and indirect effects (path analysis) of physiological characters and kiln dust pollution on yield of wheat.

Character No.	Characters	Total correlation	Direct effect	Totality of indirect effect	Influencing character(s) and its indirect effects
8.	Chlorophyll content	0.7345	-0.0250	0.7595	(12) 0.8908
9.	Rate of transpiration	0.8525	-0.0393	0.8918	(12) 1.0515
10.	Max. RGR	0.6170	-0.1505	0.7675	(12) 0.8466
11.	Max. NAR	0.6520	-0.0989	0.7509	(12) 0.8566
12.	Dust pollution	-0.9604	-0.8201	0.2314	(10) 0.1069

4.20.2.5 <u>Effects under general pollution</u> :

Overall effects of dust pollution (Table 20.2(e) revealed more or less similar effects to that of cement dust pollution.

In general, the kiln dust pollution exhibited direct effect on yield while cement and overall dust pollution noted lower negative direct effects and greater indirect effects through other parameters on yield.

Soil dust pollution showed greater direct effects and low effects through other characters.

Table 20.2(e). Direct and indirect effects (path analysis) of physiological characters and overall dust pollution on yield of wheat.

Character No.	Characters	Total corre-lation	Direct effect	Totality of indirect effect	Influencing character(s) & its indirect effects
8.	Chlorophyll content	0.4501	0.0088	0.4413	(9) 0.1997 (12) 0.1842
9.	Rate of transpiration	0.6671	0.2671	0.4000	(10) 0.2064 (12) 0.1769
10.	Max. RGR	-0.8635	-0.6512	-0.2122	(11) -0.1100
11.	Max. NAR	-0.6749	-0.1258	-0.5491	(10) -0.5693
12.	Dust pollution	-0.4735	-0.2249	-0.2486	(9) -0.2101

4.21 Contributions of Yield Predictors of Wheat

In order to assess the relative importances of different characters explaining the variations in yield of wheat, the direct contribution of each character has been worked out from the direct effect obtained in the path analysis. Similarly, the total contribution of these characters have been estimated through multiple correlation. The estimated different types of contributions of these characters are presented in Table 4.21.1 for biometrical characters along with dust pollution.

Table 21.1. Direct contribution of different biometrical characters in wheat yield.

Sr. No.	Characters	Percentage contribution of the character under				
		Dust free environment	Soil dust pollution	Cement dust pollution	Kiln dust pollution	Overall dust pollution
1.	Thousand grain weight	0.88	0.32	2.21	0.71	0.01
2.	No.of spikelets/ earhead	16.97	8.53	5.39	6.54	1.78
3.	No.of grains/ earhead	3.32	5.54	0.23	1.34	0.67
4.	No.of ears/m^2	28.14	44.44	72.88	24.54	40.90
5.	Max. LAI	0.47	0.13	0.07	0.15	0.01
6.	Biomass/m^2	6.10	1.24	11.59	8.19	14.36
7.	Dust concentration	-	5.34	0.62	38.45	0.11
8.	Total direct contribution	55.88	66.54	92.99	79.92	57.84
9.	Total indirect contribution (R^2-(8))	42.79	32.22	4.11	16.91	38.82
10.	Total residual contribution ($1-R^2$)	1.33	1.24	2.90	3.17	3.34

The biometrical characters showed 55.88% total direct contribution to yield under dust free environment. The total direct contribution of these parameters was increased under dust polluted environment (Table 21.1). Maximum direct contribution on biometrical parameters to yield was observed in cement dust polluted environment (92.99%) followed by kiln dust (79.92%), soil dust(66.54%) and overall dust pollution (57.84%) in order. The total indirect contribution of these parameters on yield was found to be maximum under dust free environment (42.79%) while minimum indirect effects were noted under cement dust polluted environment. Soil dust polluted environment exhibited 32.22% total indirect contribution while over all dust pollution recorded 38.82% total indirect contribution through these parameters. The total residual effects were maximum (3.34%) under overall dust polluted environment followed by kiln dust (3.17%),cement dust(2.90%), dust free environment (1.33%) and soil dust polluted environment (1.24%) in order.

Scrutiny of the data presented in Table 21.1 showed maximum contribution of no.of ears/m^2 in wheat yield under both dust free and dust polluted environments. Maximum contribution of 72.88%(by this character) was recorded under cement dust polluted environment. Soil dust ranked second (44.44%) followed by overall dust(40.90%), dust free environment (28.4%) and kiln dust (25.54%)

in order. The other biometrical characters behaved varyingly under different environments.

Under dust free environment number of spikelets/earhead contributed next to ears No./m^2 (16.97%) followed by biomass/m^2 (6.10%) and number of grains/earhead (3.32%) in order. Thousand grain weight and maximum LAI showed low contribution.

Under soil dust polluted environment number of spikelets/earhead (8.53%) was observed to be a second best variable followed by number of grains/earhead. Dust concentration contributed 5.34 % to the yield. Biomass/m^2, thousand grain weight and maximum LAI exhibited low contributions.

Under cement dust polluted environment biomass/m^2 (11.59%) ranked second in order. Number of spikelets/earhead (5.39%) and thousand grain weight (2.21%) were the other contributing characters to yield. Number of grains/earheads, maximum LAI and dust concentration showed poor contribution.

Under kiln dust, concentration level of dust pollution contributed maximally to yield (38.45%). However, the effect of dust concentration level on yield were negative (Table 18 and Table 20.2 (d). The next yield contributing character under kiln dust polluted environment was number of ears/m^2 (24.54%), biomass/m^2 contributed 8.19% followed by number of spikelets/earhead (6.54%) and thousand grain weight (1.34%) in order. The characters, maximum LAI and number of grains/earhead showed lower contributions.

Under overall dust pollution the maximum contribution was indicated by number of ears/m^2(40.90%) followed by biomass/m^2 (14.36%) and number of spikelets/earhead (1.78%) in order. Thousand grain weight, number of grains/earhead, maximum LAI and dust concentration poorly contributed to the yield.

In general, types of dust exhibited low direct contribution to yield except kiln dust wherein the direct contribution to yield was very high (38.45%). Considering the negative inter-relationship between dust pollution and yield and yield attributes the overall effects of dusts pollution are inhibitory.

4.22 Contributions of Yield Predictors (Physiological Parameters) of Wheat

The estimated different types of contributions of physiological characters and dust pollution in wheat yield are presented in Table 21.2.

Table 21.2 . Direct contribution of different physiological characters in wheat yield.

Sr. No.	Characters	Percentage contribution of the characters under				
		Dust free environment (%)	Soil dust pollution (%)	Cement dust pollution (%)	Kiln dust pollution (%)	Oberall dust pollution (%)
1.	Chlorophyll content	0.15	0.54	4.42	0.01	0.01
2.	Rate of transpiration	0.22	3.54	4.95	0.01	7.13
3.	Max. RGR	88.53	71.74	23.29	2.27	42.41
4.	Max. NAR	0.29	Nil	6.37	0.98	1.58
5.	Dust concentration	-	4.67	1.85	1.42	5.06
6.	Total direct contribution	89.19	80.49	40.88	4.69	56.19
7.	Total indirect contribution (R^2-(6))	8.80	16.58	55.29	88.85	37.53
8.	Total residual contribution ($1-R^2$)	2.01	2.93	3.83	6.46	6.28

Maximum total direct contribution of physiological parameters to yield was observed under dust free environment. Total direct contribution of these parameters was low under dusts polluted environment than dust free environment. Under dust polluted environment maximum direct contribution of physiological parameters to yield was observed under soil dust polluted environment (80.49%) followed by over all dust polluted (56.19%), cement dust polluted environment (40.88%) and least under kiln dust polluted environment (4.69%). The total indirect contribution of physiological parameters was minimum under dust free environment (8.80%). The physiological characters exhibited greater total indirect contribution under dust polluted environments. Maximum total indirect contribution was observed under kiln dust (88.85%) followed by cement dust (55.29%) overall dust pollution (37.56%) and soil dust polluted (16.58%) in order. The total residual effects were meagre (2.0 to 6.0%).

Percent direct contribution of physiological parameters to wheat yield (Table 21.2) indicated maximum contribution of maximum RGR 88.56% to yield under dust free environment. Maximum NAR, rate of transpiration and chlorophyll content recorded poor contributions.

Under soil dust polluted environment maximum RGR exhibited maximum contribution (71.74%), followed by dust concentrations (4.67%) and rate of transpiration (3.54%) in order. Chlorophyll content and maximum NAR poorly contributed to yield.

Under cement dust polluted environment maximum RGR contributed 23.29% followed by maximum NAR 6.37%, rate of transpiration 4.95%, Chlorophyll content 4.42% and dust concentration 1.85% in order.

Under kiln dust, the physiological characters recorded low contribution to yield (2.27%) by maximum RGR, 1.42% by dust concentration, 0.98% by maximum NAR and 0.01% by chlorophyll content and rate of transpiration, respectively.

Under overall dust pollution, maximum RGR recorded maximum contribution (42.41%). The second best character contributing yield was rate of transpiration (7.13%) followed by dust concentration 5.00, maximum NAR 1.58 in order. Chlorophyll content showed too low contribution (0.01%).

In general physiological parameters can explain the variation in yield under dust free and soil dust polluted environment only.

* * *

CHAPTER V

DISCUSSION

Environmental pollution is a major universal problem. Rapid industrilization and improper methods of waste disposal have intensified the gravity of this problem. Dust pollution due to emission of minute particles of 0.1 to 100 μ size into environment is common in developing countries. The types of dust causing pollution are soil, cement, kiln, ash (thermal power stations), coal field etc. The dust particles are deposited on the surface of soil and canopy of vegetation. These deposited particles when come in contact with water or vapour form hard crust. The cement dust and kiln dust comprise , oxides of calcium, potassium, sodium which form corosive hydroxides when come in contact with water. The dust when deposited on leaves reduces the availability of light to the chlorophyll pigments, alters gaseous exchange system by blocking stomatal appertures and decreases synthesis of chlorophyll (Singh, 1980; Singh and Rao, 1980 and 1981, Prasad and Inamdar, 1990 a, b). Data presented in Table 12 indicated lower rates of transpiration under dust polluted environments than control (dust free environment). The decreased rate of transpiration may be due to partial to complete blocking of stomatal pores by dust deposition on leaves which may have caused hinderance in gaseous exchange. Similar results were recorded by Czaja, (1966); Lerman, (1972); Singh and Rao, (1981). It has also been reported that dust deposition on canopy increases leaf temperature (Mark, 1963; Singh and Rao, 1981). The dust pollution has thus, affected major physiological processes of the plant which in turn have retarded growth and productivity (Singh and Rao, 1968).

5.1 Effect of Dust Pollution on Growth

Growth of wheat is expressed by height of plant, leaf area and number of tillers/m^2. The plants growing under dust pollution showed decreased height, tiller number and leaf area as compared to control plants. The decreased leaf area had reduced total photosynthetic area of plants. Decreased tiller number had also contributed to reduce total leaf area/plant. The plants growing under dust polluted environment were thus, poorly developed as compared to plants growing under dust free environment (control). Amongst the dusts, cement and kiln dust exhibited greater detrimental effects on growth parameter as compared to soil dust pollution. Retarded growth of plants under dust polluted environment may be due to reduced rate of photosynthesis and improper supply of assimilates. Reduction in height, leaf area and tillers/plant have been reported by Parathasarathy _et al_. (1975);

Singh and Rao (1980); Indhirabai et al. (1989); Shukla et al. (1990); Prasad and Inamdar (1991) and Prasad et al. (1991).

The types of dust and their concentration levels had also affected dry matter assimilation of plants. The plants growing under polluted environment exhibited lower dry matter production which resulted in decreased biomass (Table 11). The decreased leaf area and LAI (Fig.1) associated with decreased dry matter/plant have lowered down crop growth rate, under polluted environment (Table 6). The data on crop growth rate at different growth stages exhibited lower growth rates under polluted environment and higher growth rates under dust free environment (Fig.2). The growth of wheat was, thus, affected by dust pollution during vegetative phase. Data on total chlorophyll content (Table 9) also indicated decreased chlorophyll contents of leaves under dust polluted environments (Lerman, 1972; Singh, 1980; Singh and Rao, 1981; Agrawal et al., 1988; Swaminathan et al., 1989 and Shukla et al., 1990). Thus, the dust pollution seems to have disorganised the photosynthetic apparatus which may have affected the rate of photosynthesis (Fig.3) [Singh and Rao (1981); Swaminathan et al. (1989); Shukla et al. (1991) and Prasad et al. (1991)]. Decreased rate of photosynthesis had reduced dry matter assimilation in plants. The rate of

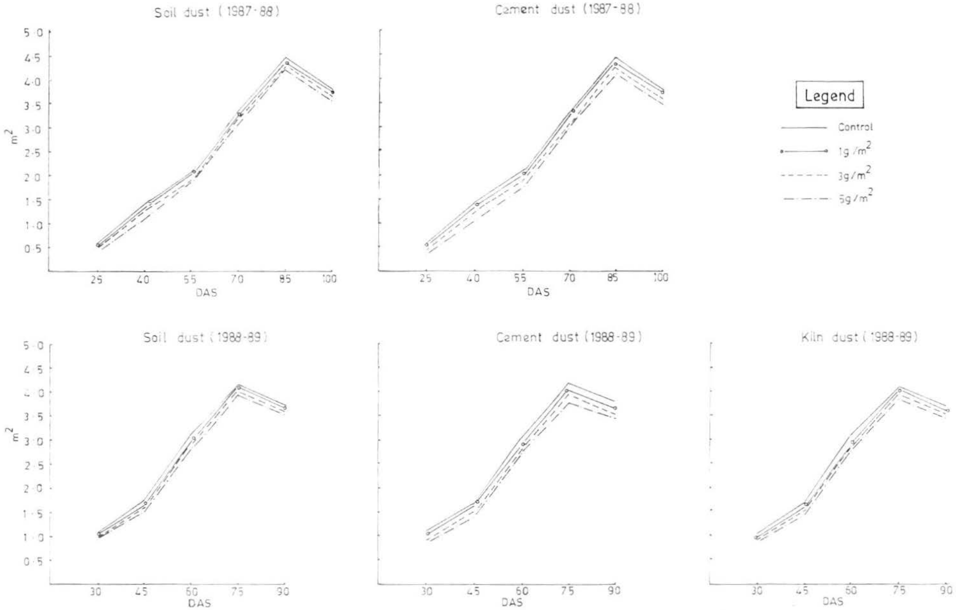

Fig. 1

EFFECT OF DUST POLLUTION ON LAI OF WHEAT

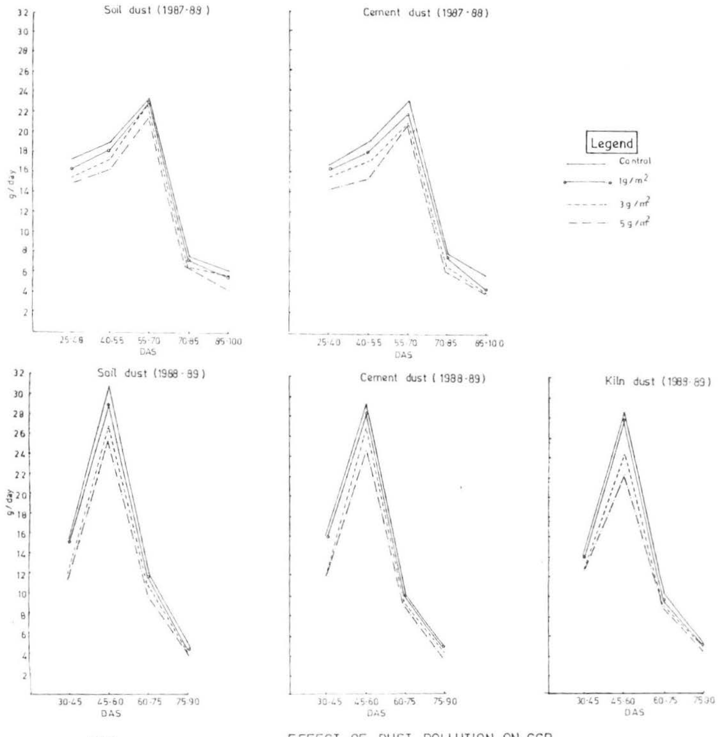

Fig. 2.

EFFECT OF DUST POLLUTION ON CGR

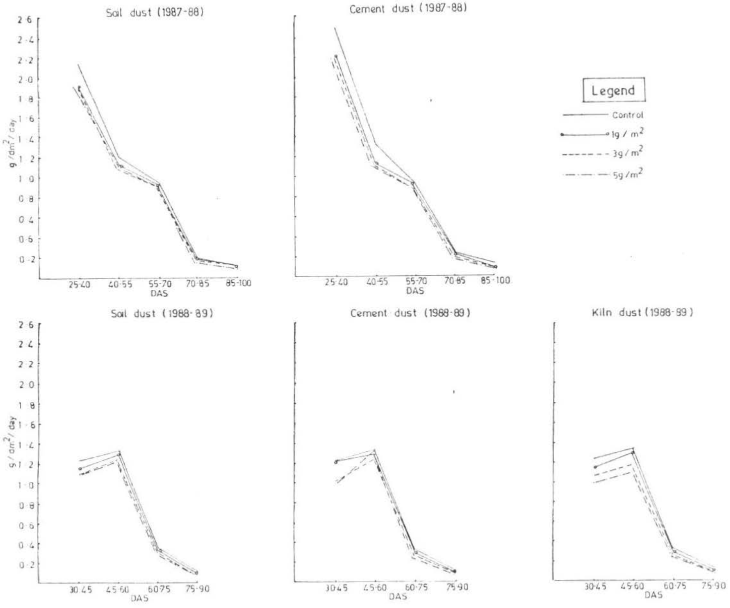

Fig 3

EFFECT OF DUST POLLUTION ON N A R OF WHEAT photosynthesis can be compensated either by increased leaf area or by increased chlorophyll concentrations. Under dust polluted environment, both of these parameters were affected by levels of dust concentration. The rate of photosynthesis and dry matter assimilation in plants growing under dust polluted environment could not be compensated by any of the above mechanisms. Reduction in biomass under dust polluted environment are reported by Singh (1980); Lal and Ambasht (1980); Singh and Rao(1981); Shukla et al. (1990); Prasad and Inamdar (1991) and Prasad et al. (1991).

The tiller survival in cereals is directly related with the nutritional status of plants. In general, the plants with higher biomass can supply assimilates to the growing tillers and thus, exhibit higher degree of tiller survival. The plants growing under dust polluted environment showed lower tiller number in initial stage of growth indicating poor tiller emergence (Table 4A and B). The plants having fewer tillers also exhibited higher degree of tiller mortality. The tiller mortality could be assessed by effective tillers/m^2, where in, it was observed that plants growing under polluted environment had significantly lower ears/m^2 as compared to the plants growing in dust free environment (Table 12). Thus, the plants growing under polluted environment exhibited lesser tillers development. The lower number of tillers/plant under polluted environment may be a result of lower biomass. The above findings are in agreement with Singh and Rao (1980); Ambrust (1986); Shukla et al. (1990) and Prasad and Inamdar (1990 and 1991).

5.2 Effect of Dust Pollution on Yield

Grain yield is a function of ears number/unit area and ear weight/plant. The ear weight is determined by number of grains/earhead and test weight (1000 grain weight). Grain weight is affected by the photosynthetic area during grain growth phase and the rate of translocation of dry matter from vegetative organs to the developing grains. The number of grains/earhead are thus, controlled by the amount of photosynthates available to the growing buds during the phase of earhead development. The availability of photosynthate depends on the rate of photosynthesis and the rate of respiration. The dust pollution forming a hard crust on leaf surfaces had decreased rate of photosynthesis by reducing the quantity of light, affecting the diffusion of CO_2 and oxygen from atmosphere into the leaf and vice-versa. The dust deposition had also decreased the rate of transpiration (Table 10) which in turn had increased leaf temperature. Increased leaf temperature increases the rate of dark respiration which may have decreased the availability of photosynthate to the growing ear. The effects of decreased availability of photosynthate were noticed by decreased biomass of wheat under polluted environment. The decreased availability of photosynthate may have affected the ear development process. The results presented in Table 13 and Table 14 indicated decreased spikelets number/earhead and number of grains/earhead under dust polluted environment. The major yield attributes, grain number and ear number were, thus, affected by dust pollution. Reduction in spikelet number and grains/ear due to cement dust pollution have been reported by Singh (1980); Singh and Rao (1980) and Borka (1986).

The another important yield attribute i.e. grain weight expressed as thousand grain weight was also decreased by dust pollution. The grain weight is mainly affected by ambient temperature during the phase of grain development and supply of photosynthate to the developing grain. Supply of photosynthate to the developing grain is again controlled by rate of photosynthesis and rate of translocation from source to sink. The plants growing under polluted environment had lower biomass and lower photosynthetic area (source). Thus, the plants growing under dust pollution may not have a proper supply of photosynthates which may have decreased thousand grain weight. The dust deposition on the ears and flag leaf may

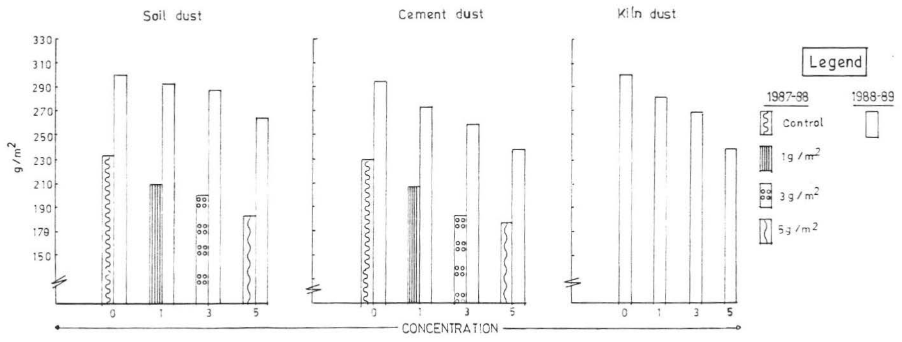

Fig. 4. EFFECT OF DUST POLLUTION ON YIELD OF WHEAT

Table 22. Percentage reduction in wheat yield as affected by concentration levels of dust.

Sr. No.	Treatments	% reduction in yield 1987-88	% reduction in yield 1988-89
1.	Soil dust		
	a) 1.0 g/m^2	9.91	3.61
	b) 3.0 g/m^2	13.79	4.85
	c) 5.0 g/m^2	21.70	12.88
2.	Cement dust		
	a) 1.0 g/m^2	10.10	10.45
	b) 3.0 g/m^2	20.34	15.22
	c) 5.0 g/m^2	23.27	22.37
3.	Kiln dust		
	a) 1.0 g/m^2	-	6.24
	b) 3.0 g/m^2	-	10.33
	c) 5.0 g/m^2	-	21.02

different statistical measures (Table 18 to 21) also indicated that the dust pollution had affected yield by modifying physiological and morphological parameters which were evidenced by higher individual indirect effects of above parameters. The biometrical yield attributes and physiological parameters showed negative association with dust pollution. The path co-efficients also indicated low direct effects. Reduction in yield under dust polluted environment have been reported by Singh and Rao (1968) and Rangasamy and Jambulingam (1973); Oblisami *et al.* (1978); Borka (1980, 1981 and 1986); Lal and Ambasht (1980); Singh (1980) and Singh and Rao (1980).

The physiological parameters were also affected by different types of dusts. The effects of dusts on biometrical and physiological parameters varied with type of dust pollution. The cement dust pollution was observed to be most detrimental followed by kiln dust and soil dust in order. The dust pollution simultaneously affected biomass as well as grain yield of wheat. These effects were reflected on harvest index. The harvest index of wheat under different concentration levels of dust pollution showed significant decrease over control during 1987-88. However, during 1988-89, the harvest index under 5.0 g/m^2 dust concentration level was significantly, higher than rest of the treatments (Fig.5). The improved harvest index under this treatment seems to be the result of simultaneous decrease in both the components (biomass and economic yield). While the results of 1987-88 indicated poor partitioning of dry matter under polluted environment. The differences in harvest indices amongst the treatments were narrow (5%). The harmful effects of dust pollution were through simultaneous and cumulative inhibitory effects on growth,

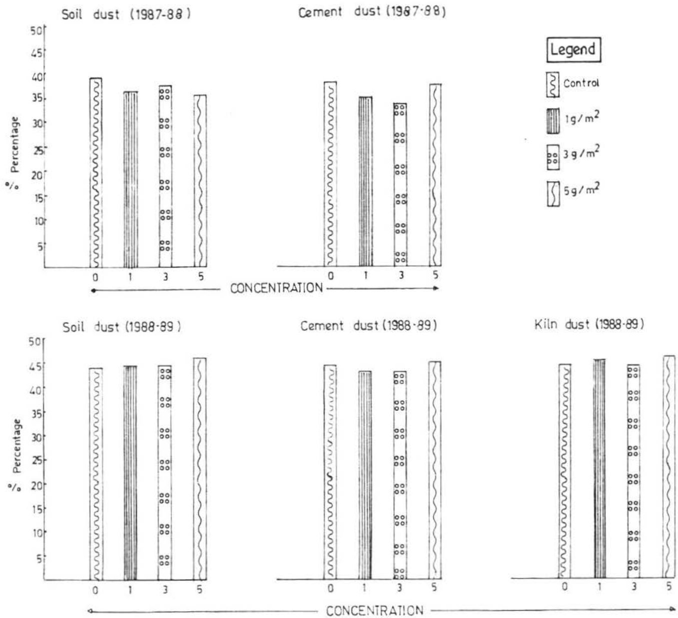

Fig. 5. EFFECT OF DUST POLLUTION ON HARVEST INDEX (HI)

yield attributes and physiological characters of wheat.

From these studies, it is concluded that -

1) Dust pollution affects plant growth, by reducing height, leaf area, number of tillers/plant and biomass (dry weight).

2) Dust pollution decreases rate of Transpiration, LAI, Crop growth rate, Chlorophyll content and Relative growth rate.

3) The yield attributes i.e. ear number/m^2, number of spikelets/ear, number of grains/earhead and 1000 grain weight were also decreased under dust polluted environment.

4) Yield of wheat decreases as the concentration levels of pollution increases.

5) Dust pollution irrespective of type of dust is detrimental to plant growth.

6) Cement and kiln dust pollution even at 1 g/m^2 concentration is harmful as it reduces yield by 10% over control. Yield losses increases with increased levels of dust pollution.

7) Amongst dusts, cement dust and kiln dust are more detrimental than soil dust.

8) Dust deposition exhibited negative association with growth, physiological, yield and yield contributing characters.

9) Percent elasticity and percent contribution determinations indicated greater indirect effects of dust pollution (through other characters) i.e. by effecting major morpho-physiological parameters.

* * *

CHAPTER VI

SUMMARY

The present investigation, "Effect of dust pollutants on growth, development and yield of wheat" was conducted during Rabi, 1987-88 and 1988-89 in the field of Department of Botany, Punjabrao Krishi Vidyapeeth, Akola. Replicated experiments were conducted in factorial randomised block design with three dusts (soil, cement and kiln dust) at four concentration levels (0.0; 1.0; 3.0 and 5.0 g/m^2). The results obtained are summarised below:

1) Plant height was significantly decreased at all concentration levels of dust pollution over control. Maximum reduction was observed at 5.0 g/m^2 dust application. Amongst dust, cement dust application significantly reduced plant heights over soil dust (1987-88).

2) Leaf area of wheat was not affected by soil dust, cement dust and kiln dust applications at most of the stages of crop growth. At 40 DAS(1987-88) and 45 DAS (1988-89) cement dust and kiln dust significantly reduced leaf area/plant over soil dust application. The concentration levels of dust applications significantly affected leaf area/plant. The leaf

area/plant gradually decreased with increased concentration levels of dust pollution.

3) Leaf area index was not affected by type of dust. However, increase in concentration levels of dusts significantly reduced LAI in both the years of study.

4) Number of tillers/m row length indicated non-significant effects of types of dust during 1987-88 and upto 45 DAS during 1988-89. During 1988-89, cement and kiln dust significantly decreased number of tillers over soil dust application at 60, 75 and 90 DAS. The effects of concentration levels of dust applications were significant. The number of tillers decreased with increased levels of dust applications.

5) The dry matter(g/m^2) was significantly lower in cement and kiln dusts than soil dusts applications. The dry matter/m^2 significantly decreased with increased concentrations levels of dusts.

6) Cement and soil dust applications showed similar crop growth rate (g/m^2/day) at most of the stages of growth during both the years. Kiln dust applications recorded significantly lower CGR value during 60 to 75 DAS while significantly higher CGR was noted during 75-90 DAS in 1988-89. The increased concentration levels of dust significantly decreased crop growth rate. Maximum reduction was observed at 5.0 g/m^2.

7) The cement dust applications showed significantly higher RGR at 25-40 DAS and 30-45 DAS growth stage during 1987-88 and 1988-89 respectively. At rest of the stages, it showed lower RGR value than soil dust applications. Kiln dust applications showed significantly higher RGR during 75-90 DAS and lower RGR value during rest of the growth stages. The mean RGR value under dust free environments were lower than dust polluted environment.

8) The lower NAR values were recorded under dust polluted environment. The plants growing under dust free environment recorded higher NAR values. NAR gradually decreased with increased concentration levels of dust applications. Minimum NAR was observed at 5.0 g/m^2 concentration levels.

9) Soil dust applications showed significantly higher chlorophyll contents than cement and kiln dust applications. The chlorophyll content significantly decreased with increased concentration levels of all dusts.

10) Soil dust recorded maximum biomass while kiln dust noted minimum biomass (g/m^2). Cement dust showed intermediate biomass (g/m^2). The biomass significantly decreased with increased concentration levels of all dusts.

11) Soil dust recorded significantly higher ears/m^2 than cement and kiln dust applications. Maximum ears/m^2 were recorded under dust free environment. The ear number significantly decreased with increased concentration levels of dust pollution.

12) Number of spikelets/earhead were significantly higher under soil dust polluted environment. Kiln and cement dusts showed significantly lower spikelets/earhead as compared to soil dust polluted environment. The spikelet /earhead gradually decreased with increased concentration levels of dust.

13) Thousand grain weight of wheat was significantly lower under cement and kiln dust polluted environment than soil dust. The 1000 grain weight was significantly lower under dust polluted environment than control. Maximum reductions in 1000 grain weight was observed at 5.0 g/m^2 dust concentration.

14) Grain yield of wheat was significantly reduced under cement and kiln dust polluted environments over soil dust polluted environment. Maximum yield was noted under dust free environment. Yield of wheat significantly decreased with every increase in concentrations levels of dust. Minimum grain yield was observed at 5.0 g/m^2 dust level.

15) Mean harvest index was higher under soil dust polluted environment. Cement dust recorded lowest harvest index. Harvest indices at different concentration levels of dust pollution were significantly lower than control.

16) Soil, cement and kiln dust pollution showed negative associations with yield, yield attributes and physiological parameters. RGR and NAR indicated non-significant association with dust.

17) The percent elasticities determination indicated maximum detrimental effects of cement dust followed by kiln dust and least with soil on yield. The detrimental effects of dusts were mainly on number of ears/m^2, number of grains/earhead, biomass/m^2, chlorophyll content and rate of transpiration.

18) The path co-efficient indicated higher direct effects on spikelets/earhead and number of ears/m^2. Rest of the characters showed lower direct effects. The total indirect effects of these characters were much higher. The dust pollution exhibiting lower direct effects had affected yield through other characters. The effects of dust pollution on most of the characters were negative.

19) Maximum RGR showed greatest direct effects on yield. Rest of the characters showed lower direct effects and higher indirect effects. Chlorophyll content and rate of transpiration were much influenced by dust pollution.

* * *

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* * *

APPENDIX I

Linear regressions of yield, yield attributes and physiological characters of wheat under influence of different types of dusts.

Sr. No.	Characters(Y)	a	b	SE ±	R^2
	Soil dust				
1.	Yield/m^2	269.43	- 7.927	4.126	0.124
2.	Thousand grain weight	36.34	- 0.464**	0.074	0.603**
3.	No.of spikelet/ earhead	16.86	- 0.319	0.166	0.124
4.	No.of grains/earhead	58.53	- 1.863	0.959	0.127
5.	No.of earhead/m^2	273.02	- 6.889	5.299	0.061
6.	Max. LAI	4.28	- 0.045*	0.020	0.163*
7.	Biomass weight/m^2	646.60	-19.455**	4.805	0.387**
8.	Chlorophyll content	3.03	- 0.148**	0.015	0.789**
9.	Transpiration	4.25	- 0.241**	0.046	0.516**
10.	Max. RGR	0.06	0.001	0.003	0.007
11.	Max. NAR	1.63	- 0.029	0.039	0.021
	Cement dust				
1.	Yield/m^2	263.11	-11.460**	3.627	0.277**
2.	Thousand grain weight	35.75	- 0.609**	0.093	0.620**
3.	No.of spikelet/ earhead	16.72	- 0.376*	0.167	0.163*
4.	No.of grains/earhead	59.44	- 2.491*	0.949	0.210*
5.	No.of earhead/m^2	272.00	-11.446*	5.034	0.166*
6.	Max.& LAI	4.28	- 0.073**	0.023	0.289**
7.	Biomass weight/m^2	646.11	-28.334**	3.460	0.721**
8.	Chlorophyll content	2.95	- 0.154**	0.016	0.781**
9.	Transpiration	4.19	- 0.316**	0.043	0.679**
10.	Max. RGR	0.06	0.002	0.003	0.021
11.	Max. NAR	1.84	- 0.049	0.049	0.037

Contd.

Appendix I contd.

Sr. No.	Characters(y)	a	b	SE ±	R^2
		Kiln dust			
1.	Yield/m^2	297.93	-11.724^{**}	0.909	0.922^{**}
2.	Thousand grain weight	34.89	- 0.238	0.181	0.109
3.	No.of spikelet/ earhead	15.59	$- 0.381^{**}$	0.034	0.898^{**}
4.	No.of grains/earhead	50.38	$- 1.745^{**}$	0.217	0.822^{**}
5.	No.of earhead/m^2	316.02	-12.941^{**}	1.145	0.901^{**}
6.	Max.LAI	4.08	$- 0.046^{*}$	0.020	0.271^{*}
7.	Biomass weight/m^2	671.30	-28.606^{**}	2.769	0.884^{**}
8.	Chlorophyll content	2.64	$- 0.070^{**}$	0.017	0.559^{**}
9.	Transpiration	4.32	$- 0.292^{**}$	0.042	0.779^{**}
10.	Max. RGR	0.05	- 0.001	0.001	0.505^{**}
11.	Max. NAR	1.33	- 0.047	0.012	0.517^{**}
		All dust together			
1.	Yield/m^2	273.30	-10.145^{**}	2.855	0.224^{**}
2.	Thousand grain weight	35.79	$- 0.470^{**}$	0.068	0.408^{**}
3.	No.of spikelet/ earhead	16.52	$- 0.355^{**}$	0.096	0.163^{**}
4.	No.of grains/earhead	57.07	$- 2.081^{**}$	0.553	0.168^{**}
5.	No.of earhead/m^2	282.18	-10.006^{**}	2.964	0.140^{**}
6.	Max LAI	4.24	$- 0.056^{**}$	0.013	0.206^{**}
7.	Biomass weight/m^2	651.90	-24.942	2.476	0.592^{**}
8.	Chlorophyll content	2.91	$- 0.133^{**}$	0.011	0.671^{**}
9.	Transpiration	4.24	$- 0.282^{**}$	0.026	0.619^{**}
10.	Max. RGR	0.06	00.001	0.002	0.007
11.	Max. NAR	1.64	- 0.041	0.027	0.032

APPENDIX III

Weekly weather data for the year, 1987-88 and 1988-89 recorded at Agriculture Meteorology Observatory, P.K.V., Akola.

N = Normal
A = Actual

Met. week No.	Date	Rainfall in mm		Temperature °C				R. Humidity %			
				Maximum		Minimum		Morning		Evening	
		N	A	N	A	N	A	N	A	N	A
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
40	1-7 Oct.,1987	17.7	26.8	33.9	32.9	18.9	22.3	80	84	44	56
41	8-14	8.5	0.0	34.7	35.4	19.4	19.0	75	76	35	28
42	15-21	1.8	7.5	34.5	33.9	18.5	20.9	71	81	34	46
43	22-28	12.6	0.0	33.4	33.9	17.6	13.4	73	64	36	22
44	29-4 Nov.	3.6	0.0	32.7	34.7	16.6	15.2	70	72	30	26
45	5-11	2.4	0.0	32.6	32.2	15.0	14.8	69	68	27	30
46	12-18	0.1	14.8	32.0	30.0	14.0	19.4	68	78	28	52
47	19-25	17.3	38.2	31.4	30.4	14.1	15.4	72	82	32	40
48	26-2 Dec.	11.5	0.0	29.6	32.1	13.8	12.1	74	80	36	24
49	3-9	0.9	0.0	29.2	30.2	12.6	10.2	71	72	31	26
50	10-16	1.1	7.2	29.4	27.6	10.8	14.6	70	84	26	51
51	17-23	0.1	0.0	29.3	27.5	10.9	6.6	68	70	29	27

Appendix III contd.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
52.	24-31	1.3	0.0	29.8	29.5	10.9	8.8	65	72	28	27
1	1-7 January, 1988	1.7	0.0	29.4	29.9	10.5	9.1	63	71	27	28
2	8-14	0.0	0.0	29.9	30.7	11.1	11.9	63	74	25	31
3	15-21	1.0	0.0	30.1	32.4	11.4	12.1	60	68	24	26
4	22-28	2.7	0.0	30.0	32.7	11.7	13.6	65	69	27	26
5	29-4 February	1.1	0.0	30.6	33.8	12.0	10.9	56	67	24	19
6	5-11	4.7	0.0	30.7	34.2	11.4	9.9	53	56	22	13
7	12-18	0.2	0.0	32.6	33.7	13.3	15.8	51	66	21	23
8	19-25	4.1	0.0	33.5	35.3	15.1	15.9	55	51	23	24
9.	26-4 March	1.7	0.0	35.0	34.9	15.5	16.1	46	43	16	17
10	5-11	2.5	0.0	36.1	37.6	16.6	17.1	39	46	14	19
11	12-18	0.9	0.0	37.6	39.3	17.5	20.0	34	42	14	18
12	19-25	0.0	0.0	39.4	37.4	19.1	13.5	31	34	11	7
40	1-7 Oct. 88	17.7	153.0	33.9	30.1	18.9	21.4	80	88	44	69
41	8-14	8.5	0.0	34.7	31.8	19.4	16.5	75	84	35	37
42	15-21	1.8	0.0	34.5	34.2	18.5	15.9	71	77	34	32
43	22-28	12.6	0.0	33.4	34.4	17.6	13.2	73	79	37	21
44	29-4 Nov.	3.6	9.0	32.7	31.9	16.6	17.1	70	82	30	37
45	5-11	2.4	0.0	32.6	30.5	15.0	11.6	69	85	27	28

Appendix III contd.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
46	12-18	0.1	0.0	32.0	31.2	14.0	9.3	68	80	28	22
47	19-25	17.3	0.0	31.4	31.0	14.1	12.6	72	71	32	25
48	26-2 Dec.	11.5	0.0	29.6	29.7	13.8	9.4	74	68	36	25
49	3-9	0.9	0.0	29.2	30.2	12.6	9.1	71	66	31	25
50	10-16	1.1	4.2	29.4	28.9	10.8	9.4	70	76	26	28
51	17-23	0.1	0.0	29.3	30.6	10.9	8.5	68	71	29	22
52	24-31	1.3	0.0	29.8	29.6	20.9	10.2	65	80	28	26
1	1-7 Jan, 1989	1.7	0.0	29.4	30.6	10.5	9.0	63	59	27	24
2	8-14	0.0	0.0	29.9	28.4	11.1	10.1	63	68	25	29
3	15-21	1.0	0.0	30.1	30.7	11.4	9.7	60	65	24	22
4	22-28	2.7	0.0	30.0	31.2	11.7	11.8	65	64	27	25
5	29-4 Feb.	1.1	0.0	30.6	34.0	12.0	9.2	56	60	24	18
6	5-11	4.7	0.0	30.7	33.6	11.4	11.5	63	55	22	17
7	12-18	0.2	0.0	32.6	33.0	13.3	12.1	51	54	21	18
8	19-25	4.1	0.0	33.5	31.5	15.1	7.5	55	46	23	16
9	26-4 March	1.7	0.0	35.0	37.1	15.5	15.2	46	43	16	12
10	5-11	2.5	12.0	36.1	34.5	16.6	17.7	39	61	14	33
11	12-18	0.9	0.0	37.6	35.3	17.5	16.7	34	62	14	21
12	19-25	0.0	2.2	39.4	37.5	19.1	20.3	31	60	11	28

THESIS ABSTRACT

a)	Title of the thesis (in capital letters)	:	"EFFECT OF DUST POLLUTANTS ON GROWTH, DEVELOPMENT AND YIELD OF WHEAT(*Triticum aestivum* L.)
b)	Full name of student	:	DEORAO VITHUJI DURGE
c)	Name and address of Major Advisor	:	Dr. B.N. Phadnawis, Assistant Professor of Agril. Botany, Department of Botany, Post Graduate Institute, Punjabrao Krishi Vidyapeeth, Akola.
d)	Degree to be awarded	:	Ph.D.
e)	Year of award of degree	:	1994
f)	Major subject	:	AGRICULTURAL BOTANY
g)	Total number of pages in the thesis	:	132
h)	Number of words in the thesis abstract	:	259
i)	Signature of student	:	D.Durge 29/6/94
j)	Signature, Name and Address of forwarding authority.	:	29.6.94 Head, University Deptt. of Botany, Punjabrao Krishi Vidyapeeth, Akola.

ABSTRACT

The present investigation "Effect of dust pollutants on growth, development and yield of wheat(*Triticum aestivum* L. was carried out in the field of Department of Botany,

Dust deposition exhibited negative association with growth, physiological yield and yield contributing characters. Percent elasticity and percent contribution determinations indicated greater indirect effects of dust pollution (through other characters) i.e. by affecting major morpho-physiological parameters.

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