A STUDY OF THE EFFECT OF PERIODIC IRREGULARITIES OF FERTILIZER DISTRIBUTION ALONG THE ROW ON THE ESTABLISHMENT, GROWTH DEVELOPMENT AND YIELD OF BARLEY

A Thesis presented at Massey College in part fulfilment of the requirements of the Degree of Master of Agricultural Science in the Victoria University of Wellington.

by

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CHAPTER I

INTRODUCTION

A considerable volume of evidence derived from field trials throughout New Zealand points to the application of artificial fertilizers (especially superphosphate) to pastures and crops as a primary factor in increased yields: The efficiency of the fertiliser is dependant on the care taken to ensure maximum recovery of the applied nutrient by the crop. This means a consideratio of factors such as, time of application, quantity applied, form of fertilizer and also correct placement and efficient distribution.

Precision is one of the aims of the agronomist in ~~an~~ attempting to step up production by the use of fertilizers. How efficient the developments to obtain these objectives have been is clearly illustrated by the increases in production obtained experimentally. The National Joint Committee of Fertilizer Application (1948) and Cooke of Rothamstead (1954) have graphically summarised the results on, time of application in relation to season, the quantity and form of fertilizer applied, and the positioning of the fertilizer in relation to the seed or plant so as to obtain maximum nutrient recovery, while avoiding any deleterious effects such as germination injury. As a result of these experiments machines have been developed to enable the recommended practices to be implemented. With higher concentrations of nutrients in the modern fertilizers lower quantities have to be applied at an accurate rate, and much work has been done in increasing the precision with which fertilizer is positioned in relation to the seed. Attention has been paid to the transverse distribution of fertilizer drills, broadcast distributors, and spinner broadcast machines and an improvement has been made by standardising all distributing units using a metered feed, viz the star wheel. Longitudinal, or "along the row distribution", on the other hand, has received little consideration. Mehring and Cummings (1930) have been the only workers to investigate the effect of variability in along the row distribution on a crop (cotton). Penman (1933) and Cook (1951) have studied the distributing patterns of the drills commonly used. It has been accepted since Cashmore's (1939) conclusions from a single trial, that the non-uniform pattern distribution of fertilizer exhibited by conventional drills was of little importance.

With greater use of more concentrated fertilizer on improved crop varieties non-uniform distribution may have several effects. There will be areas of high rates of application interspersed with areas of low, or very low rates. High salt concentration in the high rate areas may cause germination injury if fertilizer is in contact with or close to the seed, even though the average rate of application is below the critical injury level. This may result in a patchiness in the establishment of the crop, and rate of growth, flowering, and onset of maturity may also be affected. Even sowing, uniform growth of the crop and an even onset of maturity are essential prerequisites to the high degree of mechanisation currently employed in agriculture.

The experiment which is the subject of this thesis was designed to investigate the effect of periodic irregularities of fertilizer distribution along the row on barley. A preliminary study of fertilizer distributing mechanisms was carried out to ascertain the pattern which would most satisfactorily simulate the irregular distribution of the star wheel distributing mechanisms employed on current seed and fertilizer drills. The work was carried out on the Field Husbandry Demonstration plots Massey College during the period 26.11.60 - 17.3.61 to ascertain the significance of irregularity in distribution of serpentine superphosphate on such measurable characters as rate of establishment, number of leaves, tillering, height, heading, grain yield, and straw yield.

Linseed was also included in the trial area, but results for this experiment are not reported in this thesis.

CHAPTER II

REVIEW OF LITERATURE

This review will be presented under the following sections:

I Distribution Patterns of Star Wheel Fertilizer Distributors

II The Effect of Non-uniform Fertilizer Distribution on The Crops

III The Response of Barley to Applications of Phosphatic Fertilizers.

IV Horizontal Diffusion of Applied Phosphate in the Soil.

I DISTRIBUTION PATTERNS OF STAR WHEEL FERTILIZER

DISTRIBUTORS

The mechanical imperfection of a fertilizer distributor, such as the star feed of the metered gravity type, has been shown by several workers to result in a consistently recurring heavy and light application pattern of distribution. The design of the hopper and of the distributing mechanism, the physical properties of the fertilizer, the prevailing atmospheric conditions and the precision of manufacture of the machine all contribute toward the resultant inefficiency of distribution.

The observations by Fincher and Mertens that German distributors did not give uniform distribution because of the condition of the fertilizer and lack of accuracy of the machines were followed up by detailed investigations into the efficiency and reasons for the inaccuracies of several types of distributors by Mehring and Cummings (1930). They found that the flow characteristics of the fertilizer, termed drillability*, as well as the imperfections in the design or construction of the machine could affect the pattern of distribution. However, with fertilizers of good drillability (an index of 75 or above) only mechanical imperfections caused significant variations in delivery. The uniformity of distribution was studied at one foot intervals along the row, and the star wheel mechanism demonstrated a periodic impulse of heavy and light applications. When related to the movement of the mechanism the heavy applications corresponded to the exposure of the first half of the delivery port by a star tooth, thus allowing the bulk of the following charge to be dropped. The light applications corresponded to the closure of the same portion of the delivery port by a star tooth. Most machines showed greatest uniformity at a drillability of 85. Fertilizer with indexes lower than this tend to bridge or cake, while the freer flowing ones dropped through the port too quickly or flowed freely from the hopper through the discharge port. In both cases vibration increased the deviation. One star feed machine demonstrated an average deviation of 38.38% when using fertiliser with a drillability of 95 (maximum delivery per foot 9.45 grams. Minimum 1.57 grams). The use of an improved design incorporating elliptical discharge ports, scrapers and knockers did not improve the pattern of distribution.

Keeble (1930) tested twelve broadcast distributors for accuracy in rate of delivery and uniformity of distribution along and across the track. For "along the track" distribution (measured at 10 yard intervals) the coefficient of variation ranged between 12% - 52% about the mean.

Penman (1933) found that when applying superphosphate with a star wheel type of distributor at a sowing rate of 92.6 lbs per acre the highest and lowest rates per 2" section of the row were 322 and 17 lbs per acre respectively with an average deviation of 57% and an 18% - 348% variation of the mean rate. The fluctuations were periodic in nature, definite impulses in distribution being associated with the position of the points of the star. The amplitude of the cycle of these impulses was 10 feet which corresponds to the distance travelled during the movement of one star tooth to the position occupied by the one before it. He also verifies Mehring and Cummings reason for the periodic impulses and also found the modifications of the discharge port shape and the use of a knocker to counteract irregular delivery inefficient. He suggests the phasing of stars to obviate adjacent rows receiving peak applications at the same time in order to reduce the effect on the crop.

Cooke (1951) tested a top delivery cylinder, a plate and scraper, a star wheel, and a vertical wheel fertiliser distributing mechanism for variations in delivery rates. He found that the delivery rate of bottom delivery types decreased with a head of less than 2" of fertiliser in the hopper. Delivery was proportional to the speed of the rotating part up to a critical level, above which the rate decreased due to slippage between the moving component and the fertiliser. Granular fertiliser maintained better condition and varied in rate with various gate openings less than did powdered fertiliser for different atmospheric moisture conditions. Variations in delivery per foot of row travelled by the drill were greatest for the star wheel and vertical wheel mechanisms, the output for the star type ranging from 40% - 160% of the mean rate. The plate and scraper mechanism on the other hand demonstrated a fairly uniform distribution pattern. Cooke also verifies Nehring and Cumings findings as to the cause of periodic impulses in delivery. He emphasised the need for a distributing mechanism capable of positively removing a definite quantity of fertilizer from the hopper per unit distance travelled by the drill. In later work (Cooke (1953)) he describes the various types of distributing mechanisms available, classifying them into

Type I Gravity feeds.

Type II Assisted gravity feeds.

Type III Metered gravity feeds.

Type IV Top delivery mechanisms.

He summarises the characteristics affecting delivery rates and distribution as presented in the table on page 7.

Cuming et al (1950) developed an endless belt feed dispenser for experimental work so as to obtain accurate metering and uniformity of distribution not available in conventional machines.

Weston (1959) tested several machines for evenness of delivery rates but only produced photographic records to illustrate uniformity of spread.

Transverse distribution of a plate and flicker, a belt and brush, and spinner broadcast distributors was examined by Hepherd and Pascal (1958). The first two machines gave reasonably even patterns of transverse distribution but the spinners produced a pattern requiring overlapping to obtain an even spread of fertilizer. Longitudinal (along the row) distribution was observed to be inferior for the plate and flicker and belt and brush mechanisms.

As a result of irregular growth of oats N.I.A.E. investigations (1960) revealed the cause to be a wide variation in longitudinal distribution in a recurring pattern with a maximum every 5 - 6 feet of forward travel (the distance travelled during the movement of one star tooth over the discharge port).

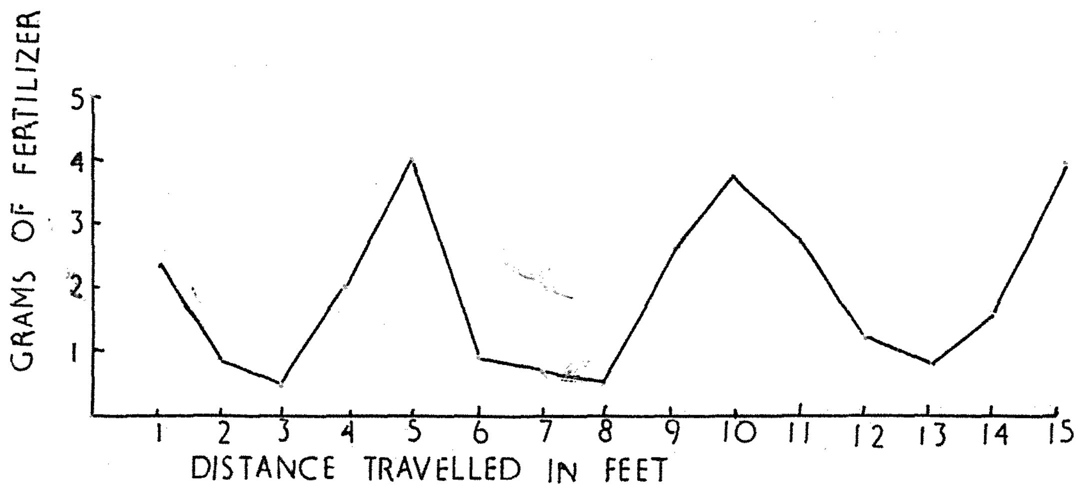
Assessment of the Effects of Various Factors on Delivery of Fertilizer by Different Dispensing Mechanisms

Key
+ serious effect
- slight effect
0 no practical importance

Factor	Type I	Type II (Worm feed)	Type III Plate	Type III Star Wheel	Type III Endless Belt	Type III Reciprocating Plate	Type III Roller	Type IV (Top	Typ Deliv
Head of fertilizer	+	-	-	-	-	-	-	0	0
Inclination of Machine	+	-	+	+	+	-	-	0	0
Incorrect speed (of dispersing component)		+	-	+	-	+	-	0	0
Inherent Periodicity		+	0	+	0	+	0	0	0
Compaction of fertilizer (upward pressure)	0	0	0	0	0	0	0	+	0
Poorly conditional fertilizer	+	+	-	+	-	+	+	0	0
Liability to excess gravily flow using free running fertilisers	+	+	0	0	0	0	+	0	0
Need for Agitator	Yes	No	No	No	No	Yes	Yes	No	N

John Deere's Development Department (1960) using Mehring and Cumings procedure obtained similar results with a star wheel mechanism. At an average rate of 2.19 grams per foot of row there was a variation of 36% - 240% about the mean with a cycle amplitude of 5 feet in one case reported.

A graph illustrating the distribution pattern of this drill is shown below.



Hutchinson's investigations (1961) revealed that the ~~cause of a~~ mosaic pattern in colour, and poor growth resulted as the effect of recurring cyclic undulations (43" - 83" amplitude) in the distribution of fertiliser which corresponded to the movement of adjacent teeth of the star wheel over the hopper orifice. He found that all machines, irrespective of modifications, showed a wide variation in delivery rate over short distances the best having a range of 67% - 146% of the mean (granular fertilizer was used). His measurements were made at 3 inch intervals using specially designed "V" trays.

All workers are in agreement as to the cause of the irregular patterns reported.

II THE EFFECT OF NON-UNIFORM FERTILIZER

DISTRIBUTION ON THE CROPS

Workers in the field of fertilizer application have reported observations of irregular responses supposedly attributable to the nature of the fertilizer distribution pattern. Mehring and Cuming (1930) refer to McGinnis 1876 who emphasised the need for thorough dissemination of manure for the best results. Haskel (1923) and Collings (1954) both report the occurrence of mosaic colour patterns and uneven growth in cereal crops resulting from uneven distribution which also interferred with orderly maturing of the crop. Mehring and Cumings (1932) investigated the efficiency of fertilizer distributors with respect to the effect of variability in distribution on the germination, earliness of blooming, rate of growth and yield of cotton. There was a definite tendency for a greater number of seeds to germinate promptly when the compound fertilizer was applied irregularly along the row. Conversely the spacing was proportionaly more regular with the uniform applications, the plants being bunched at the low points of delivery for the irregular distributions. Uniform applications prompted more rapid and even growth. When the coefficient of variability of fertilizer distribution V was 0 there was far earlier flowering than at V 8, 9, 10 or 56. The yield was increased by 47% above the average for the irregular machines when the concentrated 12:24:12 compound fertilizer was applied uniformly, and it was reduced as the V increased. Uniformly applied fertilizer in nearly every instance hastened maturity to a greater extent than the same amount applied irregularly.

Cashmore et al (1939) applied concentrated nitrogenous fertilizers in the spring to autumn sown wheat at 3 cwt per acre in varying patterns of uniformity. The treatments comprised broadcast, 7" 14" and 28" bands of fertilizer spaced 7" 14" and 28" apart respectively, and an unmanured control. These gave colour differences due to banding of the fertilizer which persisted until harvest. The yield response was a highly significant increase for broadcasting over control, and the 7" band treatment was also significantly superior to the evenly manured treatment. The 14 and 28" band treatments produced no significant differences. Cashmore said that further work was required due to the influence of the dry season which probably reduced the availability of water necessary to effect an efficient nitrogen response.

Cross (1959) observed periodic irregularities in the growth response of linseed to applied superphosphate, the effect being attributed to the delivery pattern of the fertilizer distributor on the drill.

Cooke (1960) has found that irregular growth and damage to the germination of cereals corresponds to the variation in delivery from a star wheel distributor when applying the concentrated compound fertilizers containing nitrates or urea.

At Massey College the frequent irregularity of response of the drilled crops, such as linseed, lupins, chou moellier, rape, mustard, and barley, to serpentine superphosphate corresponded to the irregularity in the distribution pattern observed for the setting of the drill used. When drought conditions prevailed at sowing the typical fertilizer response pattern was most marked and in many cases persisted till maturity.

III THE RESPONSE OF BARLEY TO APPLICATIONS OF PHOSPHATE FERTILIZERS

Barley yield responses to phosphate vary according to the prevailing soil and environmental conditions. The increases are especially marked in phosphate deficient soils under drought conditions according to Domanski (1958) working on Dutch soils. Loizides (1958) found inconsistent responses due to a residual build up of phosphate from previous applications. The New Zealand Department of Agriculture (1957 - 1960) reports results of manured trials which indicate that the greatest number of significant responses occur at an application rate of 2 cwt. per acre. The increase in yield in these cases varies from 5 - 16 bushels per acre. Soils high in phosphate due to a build up by previous applications or a naturally high phosphate status did not generally demonstrate significant responses.

Rothamstead Experimental Station (1954), Cook (1954), The National Joint Committee of Fertilizer Application (1948) and Reith (1952) all concluded that 1 cwt per acre of phosphatic fertilizer placed in close proximity to the seed produced yields equivalent to those obtained from 2 cwt per acre broadcast. Placement allowed a quicker uptake during early growth and the barley plants were more drought resistant due to better development of the rooting system.

McLeod (1960) applied 1 cwt of superphosphate to a spring cereal? and obtained a significant increase of 10 bushels per acre, a greater number of heads per 10 feet of row and a greater number of tillers per plant, but no improvement in germination.

IV HORIZONTAL DIFFUSION OF APPLIED PHOSPHATES IN THE SOIL

The horizontal movement of phosphate through the soil has generally been found to be negligible, the root systems of plants having to be extended to the zone of application before any benefit is derived.

Olsen et al (1950) found a maximum vertical movement of 3" - 4" with no appreciable horizontal diffusion. Lawton (1954) using radioactive phosphate, P 32, detected a maximum horizontal movement of 1" with moisture at field capacity. Also using P 32 Heslep and Black (1954) detected a maximum diffusion of 3 - 4 cms after 4 weeks.

Wit (1953) suggests that the distance of placement from the crop row affects only early growth and not the final yield. ~~Tesser~~ Tesar et al (1954) used radioactive phosphate on alfalfa seedlings and found that plants placed 0", 1", 2", 3", and 4" to the side of a fertilizer band 1½" deep, obtained 98%, 66%, 15%, 3% and 0%, respectively, of their phosphate from the applied fertilizer after one month. Two months after seeding the plants had obtained 77%, 62%, 50%, 24% and 7%, respectively, of their phosphate intake from the band application. Seedlings therefore have to be directly over the fertilizer band or within 1" to one side to obtain more than 60% of their phosphate from the applied fertilizer in the first 2 months. Chamenchenko (1956) found phosphate uptake slower at 2 - 5 cm from the seed row compared with contact placement and at 8 - 10 cm a further delay in uptake occurred.