COMPONENTS OF WHEAT YIELD

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INTRODUCTION

For the last ten years or so staff in the College's Plant Science Department have been conducting an intensive research programme on wheat, starting with some controlled experiments on the effects of temperature and moisture stress on grain setting and continuing in recent years with fairly complex field work involving different rates of sowing, irrigation and cultivars, and nitrogen applied at contrasting times. Many valuable results have been obtained from this work, but perhaps the main lesson was to be reminded that wheat yield is not a simple concept but is made up of a number of components which together decide how many grains are being produced per unit area and how large they are to become. Equally important and closely related was the realisation that each of these yield components is determined at a different stage in the life of the plant and is thus capable of being influenced by weather or management at a critical time during the season.

COMPONENTS OF YIELD

At its simplest we can say that the amount of grain produced by a crop depends in the first instance on the number of ears that are present. Thus, unless the ears are unusually large, we can not expect to obtain a good yield from a thin stand. Grain number per ear is also very important, but here we are dealing with two components, one being the number of spikelets and the other the grain set - that is the number of grains contributed by each spikelet. However, in accounting for total yield we must also consider the weight of the individual grain, so that the complete equation of yield components should be given by:

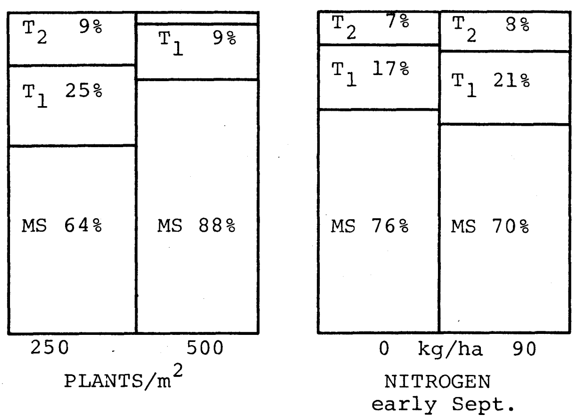
grain yield/ha	=	number of ears/ha
	X	number of spikelets/ear
	X	number of grains/spikelet
	X	weight/grain

The important question, of course, is which of these components has the greatest influence on yield. But before we look at the evidence which is available to us in this respect, we must remind ourselves that each is determined at a different time and that many weeks elapse between the first and last being fixed.

Take for example the number of ears in the crop. We first become conscious of this component in early to mid-November after the ears have emerged, but in fact the processes leading up to this event began soon after plant establishment when tillering started and continued well into spring and the beginning of stem elongation. To start with, it is the seed rate itself which has a large bearing on ear numbers, and this is coupled with the degree and time of tiller production during winter and early spring. Not only the number of tillers formed is important, but also how many die as the successful ones become dominant.

Our results show that by far the most important contributor to yield is the main shoot of each plant, followed at a considerable distance by the first tiller, and with the second tiller still further behind in importance. The actual contributions depend on the sowing rate and the amount of nitrogen applied, as shown in figure 1.

FIGURE 1. % CONTRIBUTION OF TILLERS TO WHEAT YIELD



It will be seen that at a normal sowing rate giving 250 plants per square metre about two thirds of the final grain yield can be attributed to the main shoots, not only because every plant is represented but also because individually they produce the heaviest grain weight. At twice the sowing rate tillering is restricted and the main shoots alone make up nearly 90% of total yield. Nitrogen applied early in spring tended to raise the importance of the tillers, but at no time did they contribute more than about a third of the total, and in any case only the first two tillers were involved at all. However, tillering remains essential as a valuable insurance policy against poor establishment.

Irrespective of the respective size of these contributions, the important point to be derived from these results is that final ear numbers are determined quite early in the life of the wheat plant, partly through the number of plants that are established and partly through the first one or two tillers to be formed.

The number of grains per ear is determined much later, to a very large extent not until the spring, after the growing point of the major tillers change from the vegetative to the flowering condition. Spikelets are differentiated in late September to early October, depending on cultivar, but floret development continues during the next few weeks while the young ear grows inside the leaf sheaths. By the time the ear emerges towards the end of November the number of florets capable of being fertilised has been determined, and we believe that grain set has virtually been finalised before anthesis. There are obviously differences in the timing of these events depending on cultivar and season, but by and large we can say that in autumn-sown wheat the first week or so of October is decisive for spikelet numbers, and a much more protracted period culminating in ear emergence is critical for fertile floret and thus grain numbers. Weight per grain depends on the ability of the plant to fill all available grain sites, and this occurs during the weeks from anthesis to some time before harvest.

MAXIMISING YIELD

From this description it should be clear that there is a whole sequence of yield-determining processes covering the growing period of the wheat plant from germination to maturity. In order to maximise yield it would of course be useful to know which of them are most important, so that treatments are applied at the right time. Useful though it may be to have a clear answer to this question, the facts are that all yield components are highly interrelated and that they can compensate for one another. This is fortunate from the point of view of ensuring a good crop, but it also makes analysis rather difficult.

Despite this reservation we can with some confidence arrange yield components in order of importance, based on a thorough evaluation of detailed results. Table 1 shows in summary form what we have concluded from five seasons' experiments with four different cultivars grown at a range of sowing rates, fertiliser treatments, and with and without irrigation at Lincoln College. The yields were generally good, usually 6 tonnes per hectare or slightly more, but at no time approaching the elusive goal of 10 tonnes per hectare. Under these circumstances we found without exception that it was the number of ears present in the crop which had the most decisive effect on yield. Next in importance was the number of grains per ear, either through the number of spikelets produced by the ear or the grain set itself, or both factors combined. Less clear and worthy of further comment is the effect of weight per grain on final yield, because in some of our experiments it was positively and in others negatively correlated, while at other times it made little difference either way.

TABLE 1. CORRELATION BETWEEN WHEAT YIELD AND YIELD COMPONENTS (1974/75 to 1978/79)

Number of ears/ha		++
Spikelets/ear)	Number of	
Grains/spikelet)	grains/ear	+
Weight per grain		+ or -

The 1979/80 season gave us another opportunity to look at this factor. In addition to Kopara which we have used consistently in our work, we also planted Rongotea and Oroua, but the main feature of the experiment was that we were able to establish a large population of fertile tillers with up to 860 ears per square metre surviving at harvest. Despite this high density, numbers of grain per ear were well maintained, and both factors combined should have given us a bumper yield, because we were able to record some 23,000 grains per square metre. As it turned out, the crops looked better than they performed, and we had to be satisfied with header yields of up to 7.8 tonnes per hectare (Table 2).

TABLE 2. GRAIN YIELD AND COMPONENTS IN 1979/80

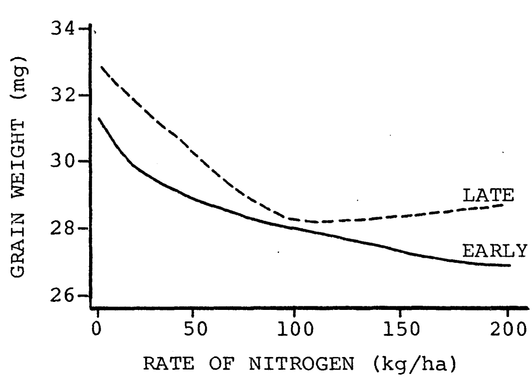
	Ears/m²	*Grains/ear*	*Weight/grain (mg)*	*Yield (t/ha)*
Oroua	860 a	29.4 b	30.2 c	7.2 b
Rongotea	708 b	30.4 b	36.0 a	7.8 a
Kopara	731 b	32.7 a	32.7 b	7.3 b

Quite clearly, there were more than enough grains present, but weight per grain turned out to be unusually low, in fact lower than we were able to measure in previous seasons; this was the component which set a limit to yield. At this stage we can only surmise as to what happened at physiological level. We believe that we are dealing with a problem similar to the depression of yield by nitrogen which we have described before and which we found again in this experiment when we applied 40 units of nitrogen in September. What may well happen is that the plant is unable to pump assimilates fast enough into the grain, when it has a large number of them to fill. The evidence suggests that carbohydrates stored in the stem play an important part in grain setting and early grain growth.

However when it comes to grain filling we depend predominantly on photosynthesis after ear emergence. In this respect the whole duration of the grain filling period is important - from the time that grain is initiated until the final weight has been determined.

More work is required to confirm details under New Zealand conditions, but it appears that a number of factors are involved. In the first place it matters how big the embryonic grain is at inception, or to put it in another way, how large the potential size of the envelope that has to be filled. Subsequently it depends on how much assimilate the plant is able to produce in relation to the demands placed upon it. Too much nitrogen, for example, may have two deleterious effects; one to create a bigger demand for carbohydrates within the plant, the other to reduce light intensity in the canopy by greater leaf growth. Figure 2 shows the effect of varying doses of nitrogen applied early (3 August) or late (6 October) on

FIGURE 2. RATE OF NITROGEN (kg/ha)



the mean grain weight of Kopara wheat sown on 30 May 1978, and it could be argued that carbohydrate supply was the main operative factor. We will continue to work on this problem, and we will also have to take into account leaf diseases and any other factor which may reduce the efficiency of carbohydrate supply to the developing grain.

Even though the national average wheat yield has not reached this point, we are well beyond the 100 bushel mark in many situations, and I personally feel that a goal of 10 tonnes per hectare is not outside our grasp.