MAIZE DENSITIES FOR FORAGE PRODUCTION IN CANTERBURY

A.R. Wallace
Applied Mathematics Division, DSIR.

D.J.G. Davies
Crop Research Division, DSIR,
Private Bag, Christchurch.

ABSTRACT

Two forage maize density trials were conducted at Lincoln during the 1975/76 season to compare early sowing October with conventional sowing time November. Sixteen density treatments, using a systematic radial spacing design were used for both trials.

The plant populations analysed were in the range 30 000 - 400 000 plants/ha.

Forage DM yields from October sowing of cultivar W346 increased with increasing plant population and maximum yield (25.5 tonnes/ha) was obtained at the highest densities. The yield curve tended to level out above populations of approximately 220 000 plants/ha. November sown PX442 showed a smaller increase in yield with increasing plant population, a lower maximum yield (19 tonnes/ha), and the yield curve levelled out above populations of about 60 000 plants/ha.

The effects of increasing plant density on the leaf, stem, cob formation, A.D.F. values and some physical characteristics of the plant are described.

INTRODUCTION

Feeding greenfeed maize to lactating dairy cows during the late summer and autumn has been regular practice on dairy farms in Canterbury (Davies, 1961). The intensification of maize growing in parts of the North Island, and the introduction of earlier maturing cultivars has resulted in the possibility of growing maize in Canterbury for grain (Hall, 1974) and silage (Jagusch and Hollard, 1973).

The present experiments were designed to ascertain the effect of sowing earlier than mid November, the usual date, on the quality and quantity of maize available as greenfeed or silage, and to estimate the plant population necessary to achieve high yields of acceptable quality forage using early maturing maize cultivars.

A systematic radial spacing design (Nelder, 1962) which gives an approximately square spacing for all densities was used. It was fitted into a rectangle in order to allocate more plants to the intermediate densities than the extremes.

Dyson and Douglas (1975) evaluated this design in New Zealand, and concluded that it adequately defined the population corresponding to maximum grain yield, the radial blocks giving significantly better fits to the yield-population regression than orthodox plots. Dyson and Douglas stress the need for care in the choice of site to avoid bias resulting from any gradient in soil or environmental factor.

METHOD

The trials at Lincoln were planted on Wakanui silt loam after a **Solanum laciniatum** crop, one with hybrid cultivar W346 on October 8, 1975 and the other with hybrid cultivar PX442 on November 7. These cultivars have relative maturity values of 90 and 95 respectively (Jagusch and Hollard, 1973).

Two seeds were planted at each position, and later thinned to one seedling. A few plants were transplanted into gaps. A basal application of compound fertiliser 4-8-12 N.P.K. was applied after sowing at the rate of 250 kg/ha. A further 50 kg N/ha as urea was broadcast on December 1. Excellent weed control was obtained with Atrazine spray. Overhead irrigation was applied three times during the late spring and summer.

The two systematically-spaced blocks were planted adjacent to each other. Plant populations ranged from 30,150 plants/ha to 400,000 plants/ha in sixteen arcs. Randomisation of the orientation of the blocks led to higher densities being on the South side of the plot for W346 (October sowing) and on the North side of the plot for PX442 (November sowing).

The ratio of radii of successive arcs was 1.09 and of successive populations $(1.09)^2=1.188$. The outermost arc had a radius of 7.3 m, and the arcs were extended to fill a rectangular plot 9.26 m x 6.0 m. The number of plants/arc varied from 17 at both extremes to 29 for arcs 5-7 (142,000 to 201,000 plants/ha). The area inside the innermost arc and a strip about 0.5 m wide outside the base of each block was filled at a density corresponding to the adjacent arc. A further protective buffer 1 m wide was planted along North and South edges of both blocks at a density of 250,000 plants/ha.

The W346 was harvested on March 10, 154 days after planting and PX442 on April 13, 1976, 158 days after planting. Where plants were damaged, diseased or missing the four adjacent plants were discarded. A six plant sample was taken at random for each arc and separated into stem, leaf, mature cobs, husk and immature cobs. Remaining plants in each arc were harvested in bulk and weighed. For the six plant samples measurements were made of fresh and dry weights, plant height, stem diameter and tiller number.

The data for Arcs 15 and 16 of the November sowing were excluded from the statistical analysis, because insufficient plants were harvested to give

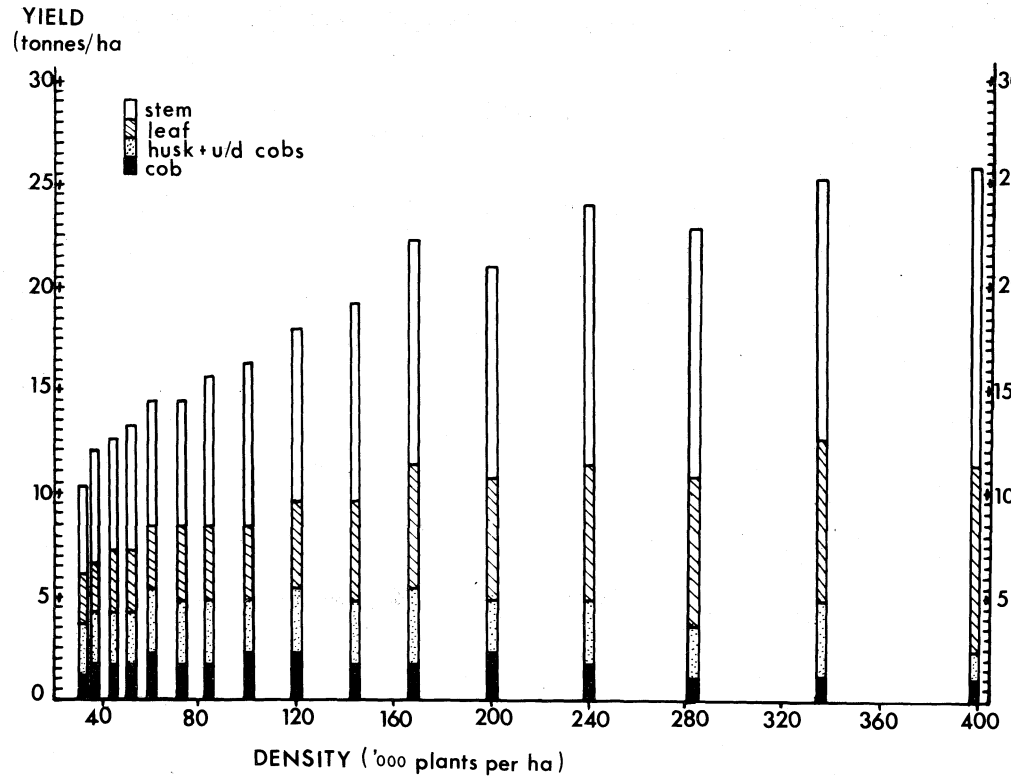

FIG. 1 Components of yield of cultivar W346 sown on 8.10.75

reliable replication.

Mean dry weights and dry matter (DM) percentages for each yield component and for the whole plant were obtained for each arc from the six plant samples. The contribution (as a %) of each component to total dry matter was then calculated. Acid detergent fibre values were determined for cob, leaf, and stem components of plants from alternate arcs.

RESULTS

Quadratic smoothing of the whole plant D.M. percentage as a function of arc number, X, led to straight line best fits as follows:

W346, (October sowing) DM% = 21.41 + 0.075 x (1)
(SE's 0.31 and 0.032 respectively)

PX442, (November sowing) DM% = 23.83 + 0.116 x (2)
(SE's 0.41 and 0.042).

The regressions were used to estimate the mean dry weight per plant of the bulk harvest of all plants in each arc. After conversion to total dry matter yields per unit area, the yield of each component was estimated for each arc using the percentage breakdown of each six plant sample. The resulting yields are depicted graphically as histograms in Figures 1 and 2.

Total Yield

The yield per hectare for each arc is plotted against density in Figure 3. The results show the usual pattern of yield increasing with increasing density up to a plateau at high densities. Yield curves from different trials can be compared with the exponential model of Carmer and Jackobs (1965) or the reciprocal equation of Bleasdale and Nelder (1960). The data from the present trials were used to derive the reciprocal equation. Figure 3 shows the yield-density relations obtained by a weighted least squares fit (Mead, 1970). The assumptions made are that the logarithm of yield per plant has constant variance, and that reciprocal of yield per plant has a linear relationship with density viz $w^{-1} = a + bp$ (3).

In this equation p is the initial mean plant density and w is the total weight per unit area divided by p (if all plants survive to harvest, w is the mean plant weight at harvest). The parameter b is the reciprocal of the asymptotic or potential yield for a particular trial. Equation (3) is a competition model for plant growth, and a check showed that there was no levelling off of the yield per plant at the lowest densities (which would indicate that competition had ceased to act).

Analysis of variance tests for invariance of the parameters a and b showed that neither could be considered invariant. The fitted equations for yield Y, per unit area (tonnes/ha) are:

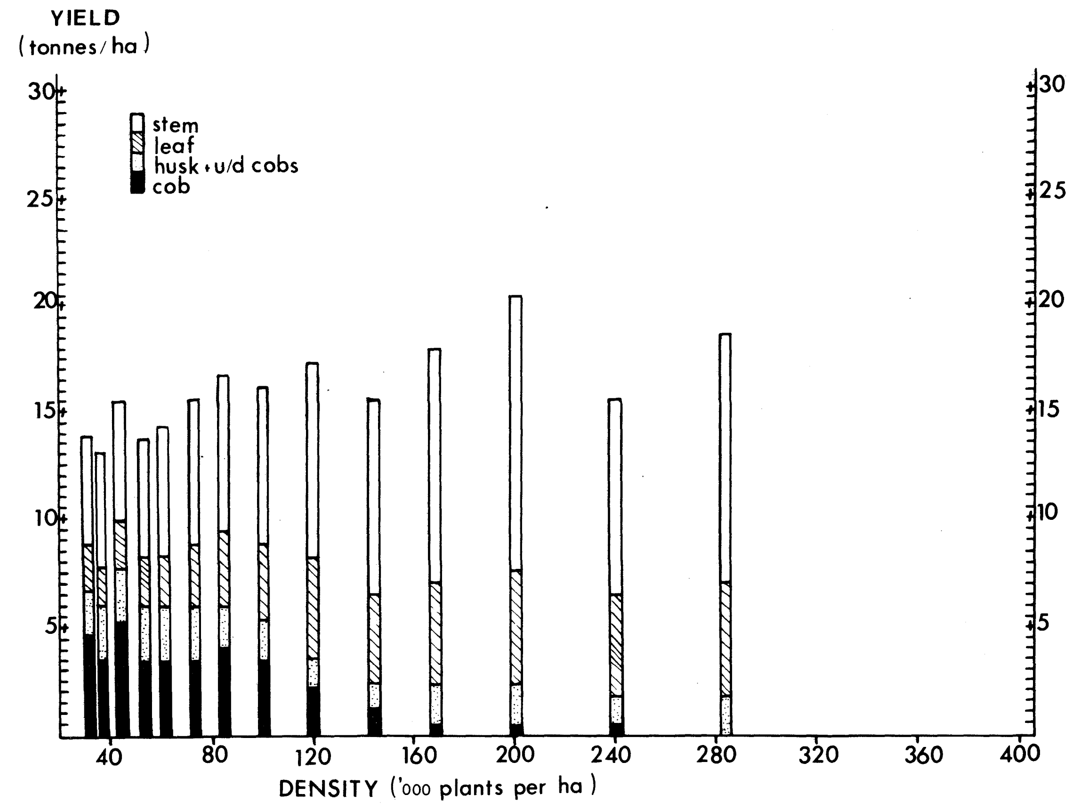

FIG. 2 Components of yield of cutivar PX442 sown on 7.11.75

W346, (October sowing) $Y = p(1.95 + 0.0361p)^{-1}$ (4)
with estimated parameter SE's of 0.122 and 0.00131 respectively.

PX442, (November sowing) $Y = p(0.72 + 0.0526p)^{-1}$ (5)
with SE's 0.156 and 0.00229

The estimated asymptotic yields of the two trials were 27.7 and 19.0 tonnes/ha for W346 and PX442 respectively. The yield curves are fairly flat above a yield of about 80% of these maxima: for W346 80% of the asymptotic yield, 22.2 tonnes/ha, was reached at a population of 216,000 plants/ha, while for PX442 80% of the asymptotic yield, 15.2 tonnes/ha, was reached at 55,000 plants/ha.

Over the range 60,000 to 150,000 plants/ha a quadratic curve was found to fit the yield data for W346 better than the reciprocal equation (Figure 3) and was used to estimate the yield at 100,000 plants/ha for this sowing. At this density W346 yielded 16.7 tonnes/ha and PX442 16.8 tonnes/ha (standard errors 0.28 and 0.49 respectively).

Components of Yield

For both varieties the effect of increasing density on leaf and stem yields was very similar, producing asymptotic curves similar to the total yield curve for W346 (Figure 3). For PX442, however, the yield reached a plateau at 201,000 plants/ha.

Regarding cob development, the effect of density in W346 was slight, cobs forming less than 15% of total yield even at the lowest densities: in PX442 the contribution of cobs to total yield declined rapidly from over 30% to less than 10% when population exceeded 120,000 plants/ha (Figure 4). There was virtually no effect of density on the combined husk and undeveloped cob yield for either variety (Figures 1 and 2), although for PX442 a substitution of undeveloped cob yield for husk yield took place as density increased above 100,000 plants/ha.

Effect on Physical Plant Characters

The total number of cobs set (including undeveloped cobs) per plant was similar for both varieties at all densities and declined in a similar way as density increased. However, the number of mature cobs decreased more rapidly for the November sown PX442 above a population of 100,000/ha. The differences in plant height at increasing densities, while relatively small, were quite definite. Above a population of 300,000/ha a slight decrease occurred for W346. A significant decrease became apparent above 200,000 plants/ha in PX442. Stem diameter (fourth node) of both cultivars declined steadily with increasing density. At the low densities for both varieties

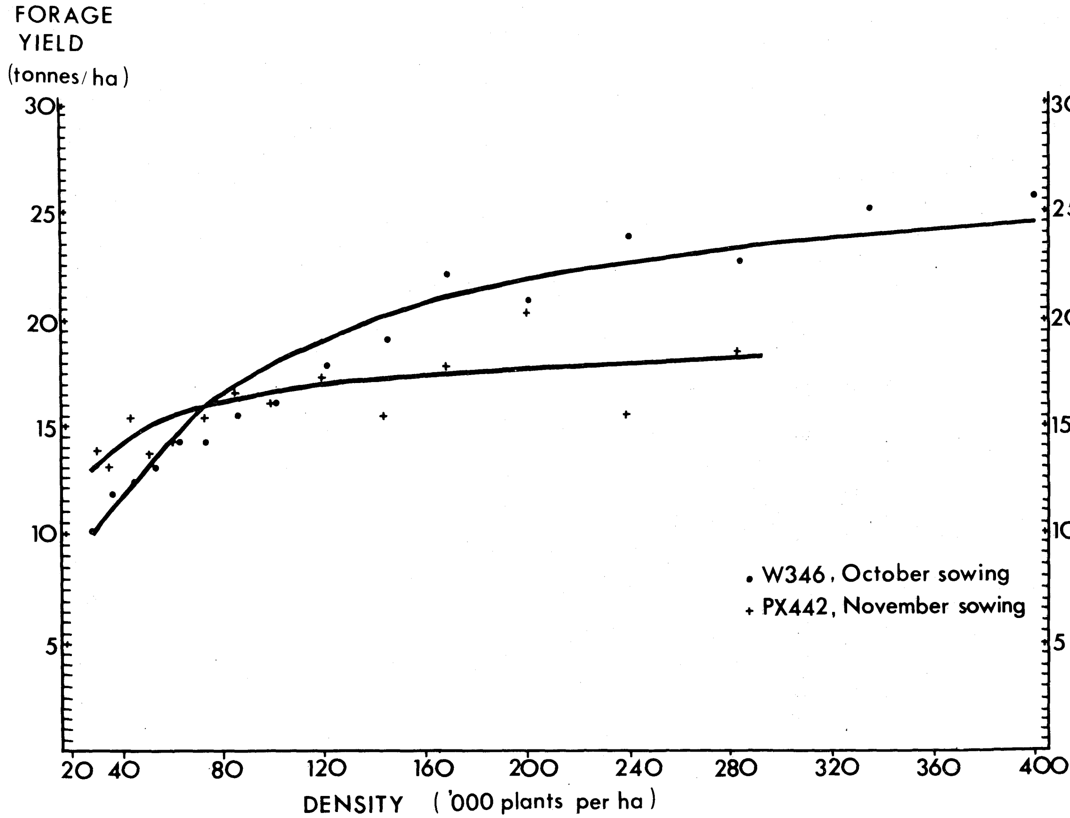

FIG. 3 Total dry matter yields and fitted reciprocal equations

TABLE 1: Physical Plant Characters (Smoothed)

Density (Plants/ha)	No. of Cobs	No. of U/D Cobs	Height (m)	Stem Diam cm	No. of Tillers
(1) W346 (October Sowing)					
50,000	1.53	1.57	1.89	2.75	1.86
100,000	1.22	0.97	2.01	2.47	1.42
200,000	0.78	0.31	2.13	2.02	1.00
300,000	0.58	0.31	2.13	1.73	1.00
S.E. (approx)	0.22	0.39	0.06	0.18	0.26
(2) PX442 (November sowing)					
50,000	1.68	1.05	2.10	2.92	1.53
100,000	0.92	0.85	2.34	2.52	1.13
200,000	0.33	0.83	2.45	2.03	1.00
300,000	0.16	1.20	2.24	1.95	1.00
S.E. (approx)	0.18	0.29	0.06	0.12	0.17

most plants produced more than one tiller. Secondary tiller production ceased above plant populations of 120,000/ha.

Effect on Dry Matter Percentage

Table 2 presents quadratic smoothed dry matter percentages for individual yield components. In W346 the leaf dry matter percentage increased only gradually with density, but for PX442 at the higher densities, the lower plant leaves senesced resulting in much higher D.M. percentages. Stem D.M. % for both varieties increased linearly with arc number (log density) resulting in a slight upward trend, tapering off at the highest plant populations. Cob D.M.% for W346 was about 20% for the lower densities and declined steadily as density increased. Grain was noticeably less doughy at the higher populations. Grain from PX442 contained 37% D.M. at the lowest density and 20% D.M. at the highest density.

Feed Value

The A.D.F. (acid-detergent-fibre) value is useful in assessing the quality of a feedstuff. Table 3 shows that the A.D.F. percentages obtained for leaf and stem for both varieties were almost constant over all densities. However there was a pronounced decrease for cobs as density increased. Because cob yields in both varieties were small (Fig. 4) the A.D.F. values

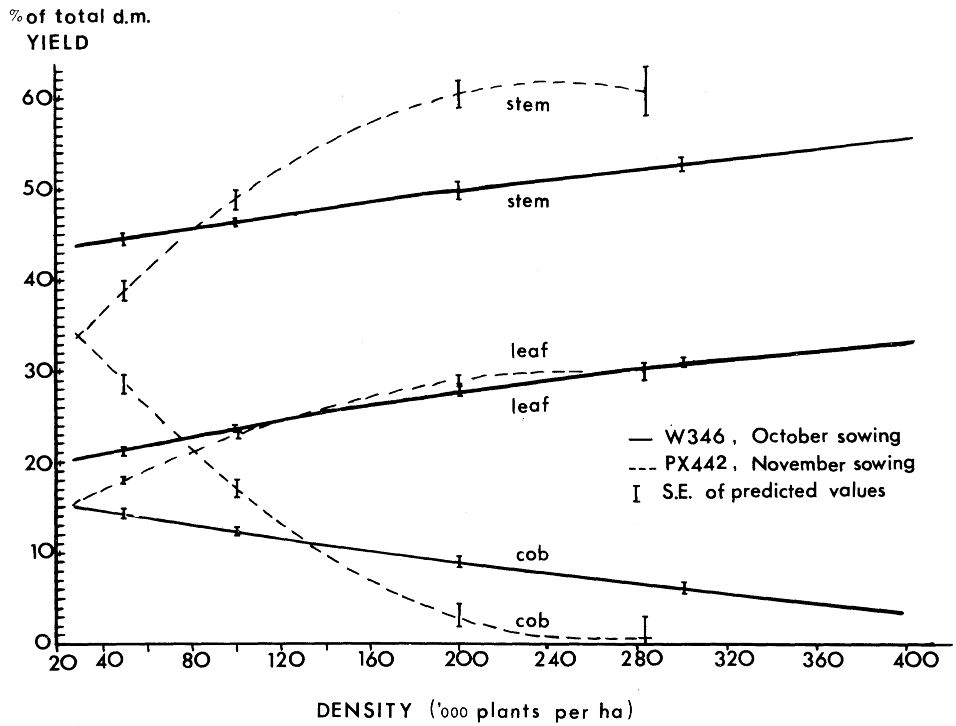

FIG. 4 Relative yields of major components

of total D.M. yield (Table 4) were unaffected by varying density for W346 but there was a slight, although non-significant, increase in A.D.F. for the later sown hybrid PX442.

TABLE 2: Dry Matter Percentages for Individual Yield Components (Smoothed)

Density (Plants/ ha)	Leaf	Stem	Cob	Whole Plant
(1) W346 (October Sowing)				
50,000	28.5	22.0	21.1	21.7
100,000	30.8	22.8	19.6	22.0
200,000	32.7	23.2	16.7	22.3
300,000	33.6	23.4	14.4	22.4
S.E.	0.49	0.27	0.48	0.22
(2) PX 442 (November Sowing)				
50,000	28.7	21.1	34.1	24.3
100,000	38.6	21.7	29.6	24.8
200,000	48.6	22.5	24.1	25.2
300,000	54.4	23.1	20.4	25.7
S.E.	1.77	0.45	1.06	0.29

TABLE 3: A.D.F. Percentages of Leaf, Stem and Cob

	Leaf	Stem
W346 (October Sowing)	28.1	29.9
PX442 (November Sowing)	29.1	29.3
S.E.	0.32	

Cob (Both trials combined)				
Density ('000 plants/ha)	50	100	200	300
A.D.F.	25.0	23.2	19.9	16.5
S.E. of Grand Mean	0.81			

DISCUSSION

In the 1971/72 season Jagusch and Hollard (1973) reported a D.M. yield 150 days after sowing of 19.6 tonnes/ha for PX442 sown at a plant population of 100,000/ha on November 10, 1971. The comparable density for the same cultivar in 1975/76 resulted in an estimated yield of 16.8 tonnes/ha of D.M.

Mean soil temperature at 10 cm from November to March was 2.3°C lower in 1975/76 than in 1971/72 (Lincoln College meteorological records). In 1971/72 W346 yielded 18.9 tonnes/ha of D.M. but when

TABLE 4: A.D.F. Percentages of Total Dry Matter

Density ('000 plants/ha)	50	100	200	300	Approx. S.E.
W346 October sowing	28.4	28.3	28.2	28.3	0.3
PX442 November sowing	27.9	28.1	28.8	29.0	0.5

sown 33 days earlier in 1975/76 the estimated yield was 16.7 tonnes/ha of D.M. at 200,000 plants/ha November sown PX442 yielded 17.8 tonnes/ha, and October sown W346 yielded 21.8 tonnes/ha. This agrees with the results of Douglas and Dyson (1972) who found that with adequate moisture, total plant dry matter yield in maize continues to increase up to populations of 200,000 plants/ha.

At 100,000 plants/ha both cultivars produced about the same yield but only the early sowing responded to increasing population. PX442 sown at the usual time for Canterbury produced reasonable cob yields at 50,000 plants/ha but at higher densities failed to fill the cobs set. W346 set cobs at all densities, but after 150 days, although the full growing season was not utilised, a D.M. yield of 25.5 tonnes was obtained.

McCormick (1974) stated the need to adjust plant populations to compensate for differences in individual plant leaf areas. Further, maximum yields may require sowing early maturing hybrids at high plant populations rather than late maturing hybrids at standard populations. (McCormick and Douglas, 1975). These results indicate that good yields can be obtained from early sowing of an early maturing hybrid at Lincoln. This aspect will be examined further. The possibility of sowing late maturing cultivars in October, for harvesting in time for sowings of greenfeed in mid April, will also be investigated.

The quality of forage maize is often regarded as being positively related to grain yield, although the evidence is far from conclusive (Bunting & Gunn, 1972). Acid detergent fibre values of total D.M. yield for these two trials were not markedly affected by density, although PX442 showed a trend towards increased fibre accumulation with increasing density. Bunting and Willey, (1959) reported a small non-significant increase in fibre as density increased.

If, as has been postulated, (A.O. Taylor Pers comm) the sugar content increases throughout the plant as density increases, this may determine the optimum density for maximum yield of high quality forage. Other agronomic factors such as lodging (not experienced in this study) and disease will also require attention.

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