input systems. Furthermore, the development of these systems is also stimulated by the realization that both local food production and many tree products remain essential to most rural people. The development of such multi-functional cultivation systems holds more promise for contributing to the conservation of essential forest and tree resources than monofunctional cash-crop cultivation systems.

Conclusion. Intensification of shifting cultivation to permanent agriculture will not in itself result in stabilized land-use and diminished pressure on forest resources. It will only do so, if the intensification is combined with measures to control possible negative effects on the socio-economic environment including changed attitudes towards forest land, and if the multi-functional characteristics of shifting cultivation are maintained.

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Netherlands Journal of Agricultural Science 34 (1986) 489-493 SYNOPSIS

Simulation of aphid damage in winter wheat

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Abstract. To study the effect of the English grain aphid, *Sitobion avenae* (F.), on dry matter accumulation in winter wheat grains, the influence of aphids on plant physiological parameters was introduced into a simulation model of wheat growth and development from anthesis onwards. A field experiment was carried out to test the model.

Simulated aphid damage agrees with field observations. In the field an aphid damage of 994 ± 322 kg ha^{-1} was measured at an aphid intensity of 490 aphid-days (number of aphids per ear times duration) and at a yield in the absence of aphids of 8414 kg ha^{-1}. At a simulated yield in the absence of aphids of 9377 kg ha^{-1}, the model predicted an aphid damage of 1241 kg ha^{-1}. The simulation results show that damage per aphid-day is highest during anthesis and decreases during the grain-filling period. The excretion product honeydew causes the major part of the damage by interference with leaf photosynthesis. Aphid damage caused by withdrawal of phloem sap is less important. Total damage increases more than linearly with the yield level in the absence of aphids, up to a level of 8000 kg ha^{-1}. Above this level, the response flattens.

Key words: simulation, aphid, wheat, damage, yield reduction, production level.

Introduction. During the last decades aphids have become an important cause of yield loss in cereals, probably as a result of changes in crop husbandry (Rabbinge et al., 1983). In the Netherlands the English grain aphid, *Sitobion avenae* (F.), is usually the most abundant species on cereals.

Experiments have revealed the complex effects of *S. avenae* on yield loss. To quantify the effects of various dynamic reduction processes on the growth and development of winter wheat a simulation approach was adopted, using quantitative data from laboratory studies. The results are used to calculate aphid density thresholds, for various wheat production levels, above which the benefits of chemical treatment exceed the costs.

Simulation model. A simulation model of post-anthesis growth of winter wheat was developed, based on a simulation model of spring wheat (Van Keulen & Seligman, in press). This model has been extended by incorporating a model describing the influence of *S. avenae* on various plant physiological parameters. The actual grain yield depends on environmental conditions such as radiation and temperature, and on the availability of carbohydrates and nitrogen. The model consists of source-sink relations for carbohydrates and nitrogen. The carbohydrate source is built up by the net photosynthesis. The nitrogen source consists of translocatable nitrogen in the plant, which is supplemented by nitrogen uptake from the soil. Carbohydrates and nitrogen are taken up by the grain and by the competing aphids, which together form the sink. Both are characterized by their potential uptake rates. Primary aphid damage is caused by withdrawal of phloem sap, which contains carbohydrates and nitrogen. This results in a reduction of the carbohydrate- and nitrogen supply available for the grains. Secondary aphid damage is caused by the aphid excretion product, honeydew, on the leaves. This reduces the maximum gross assimilation rate at light saturation (AMAX) and the light use efficiency (EFFE), resulting in a decrease of gross photosynthesis (Rabbinge et al., 1981). These effects were quantified in detailed laboratory studies, and introduced into the simulation model. The simulation starts at anthesis (DC 60, Zadoks et al., 1974). The model is initialized with the dry weights and nitrogen fractions of the plant organs at anthesis. Measured daily minimum and maximum temperature, daily total radiation and aphid densities are used as forcing functions.

Field experiment. A field experiment with winter wheat (*Triticum aestivum* (L.) cv. Arminda) was carried out at the experimental farm 'De Eest' in Nagele, Noord-Oost Polder in 1984 to test the model. The experiment consisted of four treatments in six replicates: control of aphids by a selective aphicide (250 g pirimicarb in 600 l water per hectare) from development stages DC 71 (at the onset of the aphid infestation), DC 75 and DC 77 and an untreated control. Aphid numbers were recorded at weekly intervals, the method and sample size depending on the density (Ward et al., 1985). Growth analysis of the crop was carried out weekly on 50 randomly chosen culms per replicate.

Results. In the field, an aphid damage (at harvest) of 994 ± 322 kg ha^{-1} has been measured at an aphid intensity of 490 aphid-days and at a yield in the absence of aphids of 8414 kg ha^{-1}. Compared to the previous crop analyses this yield is very low. Aphid damage of 1241 kg ha^{-1} is simulated at a yield in the absence of aphids of 9377 kg ha^{-1} (Fig. 1).

Fig. 2 shows the different damage components simulated by the model, and their relative importance in total aphid damage at a yield in the absence of aphids of 8562 kg ha^{-1}. Although the aphid infestation started at the end of June (with a population peak at 25 July, see Fig. 1), the simulated damage did not start until the second half of July. This is due to the reduction of the reserves in the stem at that time, i.e. when

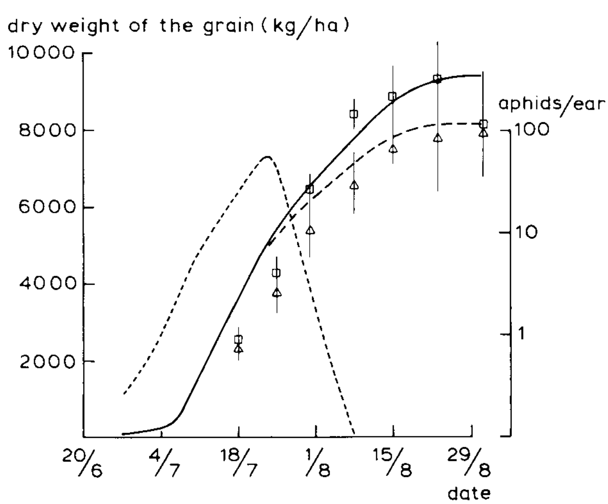

Fig. 1. Simulated (——) and measured (□) dry weight of the grain in the absence of aphids, simulated (– – –) and measured (△) dry weight of the grain in the presence of aphids and the aphid population (-----), as a function of time.

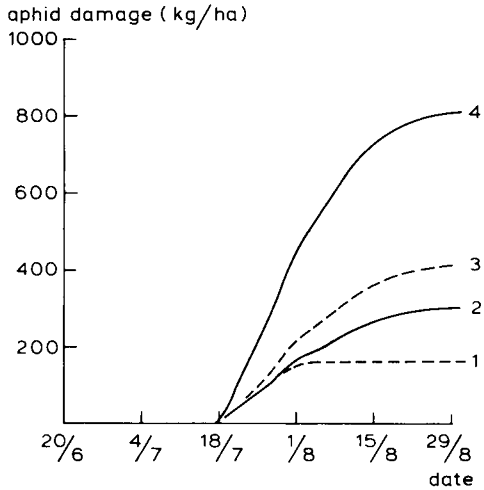

Fig. 2. Simulated damage components (kg ha^{-1}) at an aphid intensity of 490 aphid-days and a yield in the absence of aphids of 8562 kg ha^{-1} as a function of time.
1. carbohydrate withdrawal
2. carbohydrate and nitrogen withdrawal
3. carbohydrate and nitrogen withdrawal + AMAX reduction
4. carbohydrate and nitrogen withdrawal + AMAX and EFFE reduction.

the grain growth changes from sink-limited to source-limited.

Primary damage caused by removal of phloem sap forms 37 % of the total damage. Carbohydrate and nitrogen withdrawal are of equal importance, although the time at which damage occurs is different: nitrogen withdrawal has a delayed effect on yield reduction.

Secondary damage, caused by AMAX and EFFE reduction resulting from honeydew deposits, is 63 % of the total damage. The combination of withdrawal of phloem sap and AMAX reduction causes 51 % of the total damage. The remainder is caused by EFFE reduction. Thus the reduction of EFFE caused by honeydew is the most important single component of the total aphid damage, according to this model. This is because EFFE is more sensitive to honeydew than AMAX, as has been shown in laboratory experiments (Rabbinge et al., 1981) and because the simulated growth is more sensitive to EFFE than to AMAX.

The simulated damage per aphid-day is highest during anthesis of wheat (5.1 kg ha^{-1} per aphid-day between DC 60 and DC 69 at a yield in the absence of aphids of 8562 kg ha^{-1}) and decreases during the grain-filling period (0.8 kg ha^{-1} per aphid-day between DC 75 and DC 77). From the field data of the four treatments, a weighted mean of 2.5 kg ha^{-1} per aphid day has been calculated over the whole period in which aphids are present (between DC 71 and DC 79).

According to the simulation model aphid damage increases more than linearly with the yield level in the absence of aphids, up to a level of 8000 kg ha^{-1} (Fig. 3). Various yield levels are simulated by changing the initial values of the nitrogen level

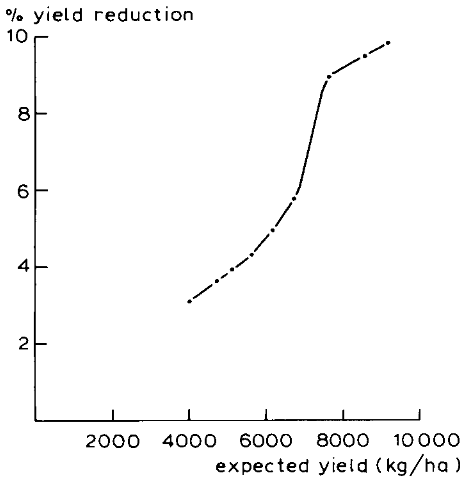

Fig. 3. Percentage yield reduction according to the simulation model at an aphid intensity of 490 aphid-days as a function of the yield level in the absence of aphids.

in the soil, the dry weight of the plant organs, their nitrogen fraction and the AMAX. At a high nitrogen level in the soil, plants take up more nitrogen and photosynthesis is stimulated, leading to a higher nitrogen and carbohydrate content in the crop. As a result, aphids take up more carbohydrates and nitrogen, and thus cause higher primary damage. Because of a longer period in which leaf surface is productive, more green leaf is covered by honeydew and secondary damage is higher. With increasing yield level, the relative effect of primary damage decreases and secondary effects due to honeydew excretion are more important. Beyond a yield level in the absence of aphids of 8000 kg ha^{-1}, aphid damage no longer increases more than linearly with yield level and saturation occurs. This is because the crop parameters affected by aphids (e.g. nitrogen fraction, leaf area index, AMAX, EFFE) are now relatively less important in limiting grain growth. These high yield levels are also determined by other crop-, soil- and meteorological parameters before anthesis which are not affected by aphids and seem to become more important.

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Crown shyness: a parameter for ageing in *Piptadeniastrum africanum*

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Abstract. The ageing of *Piptadeniastrum africanum* within the forest follows a well-defined pattern, that consists of different stages, which can be determined from large-scale stereoscopic aerial photographs. The main parameters of this pattern are branch orientation, crown stratification, depth of foliage and crown shyness.

Crown shyness indicates a phase of declining vigour of *P. africanum* and is seen as a parameter for ageing in the senescent stages of the life of *P. africanum*.
Key words: Piptadeniastrum africanum, ageing characteristics, crown morphology, crown shyness, senescence, aerial photography.

Introduction. Vooren (in prep.) proposes a silvicultural system for tropical forests, in which harvesting is modelled on the natural mortality process within the forest and harvest-ripe trees are detected by means of aerial observations. This study was set up to contribute to the insight in the structure and the evolution of mature tree-crowns and to establish parameters for this evolution, which can be evaluated by remote sensing techniques.

Materials and methods. Crown alteration was studied on *P. africanum*, a common species in Africa with potential commercial value (Anon., 1974). The species is easily recognizable and accessible for both ground and aerial observations. Its architectural growth model (Troll's) was described by Hallé et al. (1978).